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GRASSLAND RESEARCH IN AUSTRALIA.

ABERYSTWYTH, FEBRUARY, 1934.

IMPERIAL BUREAU OF PLANT GENETICS : HERBAGE PLANTS

BULLETIN No. 14.

GRASSLAND RESEARCH IN AUSTRALIA : FUTURE PROGRAMME
AND CONTRIBUTIONS ON PASTURE TECHNIQUE.



IMPERIAL BUREAU OF PLANT GENETICS : HERBAGE PLANTS
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EDITORIAL NOTE.

This Bulletin will serve to give a clear picture of the various projects in grassland research being studied in Australia at the present time; the various items of Section A have been extracted from the "Register of Agricultural Research in Progress in Australia," published by the Commonwealth of Australia Council of Scientific and Industrial Research, Melbourne, 1933. Pages 1-17 of the Register have been quoted in full; other items have been taken from various parts of this extensive publication, which comprises 288 pages in all.

Arrangements have been made for the publication in future numbers of *Herbage Reviews* of articles by several Australian investigators on the progress of some of the research items enumerated under the head of Research Programme.

Section B of this Bulletin contains two further articles on the technique of pasture investigations. The first series of articles published on this subject by the Herbage Bureau will be found in our Bulletin No. 11, "Technique employed in Grassland Research in New Zealand." The articles now published from the Waite Institute, Adelaide, and the Victorian Department of Agriculture represent the Australian contributions to the interchange of opinions and experience on this subject. Articles by investigators on the staff of the Welsh Plant Breeding Station will be published in the near future.

R. O. WHYTE.

(Names of Corresponding Editors and details of Herbage Publication Series at end of Bulletin).

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FOREWORD.

Grass represents the raw material which when worked up forms a very important proportion of man's food and clothing. This being so, it might be expected that the organized study and improvement of grassland would have played a leading part in the life of civilised communities. Yet it is wholly surprising to find how recent a development is the trend to grassland-mindedness among the leading nations of the modern world. There is now evidence, however, that in recent years a growing realization of the value of grass has come about and the subject of its improvement has already attracted the attention of a considerable body of workers. That the countries of the British Empire are playing a leading part in this development may be gathered from the register reprinted in this bulletin in connection with herbage researches conducted in the Commonwealth of Australia. These researches cover a wide field of problems—an extraordinarily interesting field inasmuch as a whole continent (in area 30 times the size of Great Britain) is brought under review.

Grassland products form an important item in the export trade of Australia ; these products include wool, meat, butter, cheese and hides. During the years preceding 1928 they represented in aggregate money value about 60 per cent of Australia's annual exports. It is likely moreover that this proportion has been exceeded during the years subsequent to 1929.

In a country so large, with problems so varied, and with a sparse population, it is of the first necessity that the relatively small band of grassland workers should be knit together very closely. The data given in the register indicate that close co-operation is being maintained and that workers in different parts of the Commonwealth are in a position to know exactly what progress is being made by a collateral worker in another part. The vastness of distances in Australia makes personal contact between workers at different Stations both geographically difficult and costly. People living in small countries like Britain often find it hard to realize these difficulties. Cairns in Queensland for example is over 4,400 miles by railway from Perth, the capital of Western Australia, a distance which would require over a week in the train each way. Cairns and Brisbane are both in Queensland, but a worker in Cairns is two days express train journey (over 1,000 miles) away from his co-workers in Brisbane—a distance equal to that of London to Rome or London to Warsaw. Distance alone, therefore, makes personal contact infrequent, and this fact makes close and well organized co-operation fundamental to the well-being of research.

The problems connected with pasture improvement in Australia are varied ; they embrace tropical and temperate conditions, including areas of very heavy rainfall at the one extreme and areas of marked aridity on the other. The "natural" pastures of Australia are characteristically lacking in, one might almost say devoid of, indigenous herbaceous legumes, and the problem of introducing into them an efficient pasture legume, whether indigenous or exotic, is one of far-reaching importance. This problem is particularly acute in tropical and sub-tropical Australia and is perhaps at present most keenly felt in the dairying districts of the Queensland coast. The fundamental importance of pasture legumes to Australia can well be judged from the expansion of pasture development which has followed upon the culture of subterranean clover in the southern parts of the Commonwealth. There are extensive areas, however, to which subterranean clover is either climatically or edaphically unsuited. The problem is to find the legume that will suit these environments in the wider sense of the term.

There is no more important project connected with the grassland problems of Australia than that concerning leguminous plants. This same problem is confronting us in Britain in relation to the improvement of our clover-deficient hill grazings. The interesting studies being

conducted by Miss Poulter at Aberystwyth concerning soil and seed inoculation by specific clover nodule bacterial organisms seems likely to have a fundamental bearing upon the whole question of the introduction of clover into new and legume-deficient areas of grassland.

Whether in general reconnaissance and survey work or in connection with more critical studies there is no more important aspect of scientific grassland technique than that represented by the two original papers published in this bulletin. A carefully made statistical record will always give a better picture of the pasture make-up than will even the most elaborate note. That is not to say, however, that notes and careful observations are not valuable; their place is to supplement the statistical record.

The botanical analysis of pastures is by no means a new subject. The beginnings of our present day technique in herbage analyses were already engaging the attention of 19th century workers. Further important contributions were made in the pre-war years of this century (Armstrong, Stapledon), while in the post-war years considerable attention has been given to the evolution of an efficient and practical technique. A variety of methods has been used by workers in different parts of the world, and there has been some effort to correlate these.

It is now fairly clear that there are three alternative schemes open to the grassland worker desiring to make a detailed survey of his material. Analysis may be made under the following heads: (a) frequency, (b) area covered, or (c) productivity. While each of these alternatives has its value, each has important drawbacks and no one of them gives a complete picture of the sward as it stands. Given these three alternatives the investigator has to decide for himself whether his time and material will allow him to use all three schemes simultaneously or whether he can use only one of them, or perhaps a combination of two. The researches conducted at Aberystwyth during the past fifteen years have shown that the collateral use of frequency and productivity gives a very useful picture of the pasture at the time of study. The inherent practical weakness of all the earlier methods was their tediousness and time-absorbing character. Having regard to this weakness the estimation methods were evolved at Aberystwyth. It is interesting to note that workers in Australia have come to the same general conclusion, namely, that botanical estimation methods can be used with advantage in pasture research. They have, moreover, shown that these methods placed in the hands of competent technicians are sound in a statistical as well as in a practical sense. A start has therefore been made towards the development of a sound technique, but the problem is by no means solved and it is to be sincerely hoped that more and more workers in Australia will be drawn into this interesting field bringing with them new ideas to build upon the foundation already laid. Meanwhile an extension of the use of existing methods is greatly to be desired if the grasslands of Australia are to be properly mapped and recorded. While frequent records in terms of observational notes are always to be commended, yet it is important that such notes should be supplemented by records of a statistical nature. This is to be stressed particularly in view of the fact that grassland investigations carried out in Australia, as elsewhere, are entering upon a more critical phase than hitherto. The empirical methods of the past served us well during the phases of initial survey work, but they are not adequate when critical and detailed investigation is called for.

WILLIAM DAVIES,
Empire Grassland Investigator.

A.—RESEARCH PROGRAMME.

I. AGROSTOLOGY AND PASTURE IMPROVEMENT.

1. GRASSLAND MAP.

Research : The preparation of a Grassland Map of Australia.

OBJECT : To furnish a broad view, in map form with accompanying notes, of the pastoral resources of the Commonwealth. It is expected to be an inventory of the major grassland and related associations of the continent. Its purpose is to serve as a guide in the work of introducing and establishing new and valuable pasture plants in definite zones and of extending, wherever possible, the areas at present occupied by successfully established useful exotics.

DEPARTMENT : Council for Scientific and Industrial Research, Division of Plant Industry.

INVESTIGATORS : A. McTaggart, B.S.A., M.S.A., Ph.D., W. Hartley, B.A., T. B. Paltridge, B.Sc. and H. K. C. Mair, B.Sc.

LOCATION : Canberra as headquarters.

RESULTS : Since the undertaking was commenced in June, 1932, a large amount of information relating to grassland and other cover has been collected as a result of the search for and perusal of publications in libraries and of the archives of Government Departments. Much valuable information has been furnished by Lands Departments through Land Surveyors and Land Settlement Inspectors and other field officers in the several States. Useful information has also been gathered as the result of a questionnaire sent out to school teachers throughout the more settled portions of Australia. At least one-half of the continent has been mapped and the necessary notes associated with a considerable area thereof have been prepared.

2. PASTURE MANAGEMENT.

(i) GENERAL PROBLEMS.

Research : Pasture improvement.

OBJECT : The introduction of winter-growing clovers and grasses, the formation of better grazing pastures, and the economic use of stock licks and mineral feeds. Problems connected with the upbuilding of fertility by the growing of legumes and application of fertilizers.

DEPARTMENT : Queensland, Department of Agriculture and Stock.

INVESTIGATORS : Fred F. Coleman and F. B. Coleman.

CO-OPERATION : C. White, Government Botanist, and E. Gurney, Agricultural Chemist.

LOCATION : Lawnton, Nerang, Caboolture, Maleny, Eumundi, Gympie, Ingham, Toowoomba and many other districts.

RESULTS : Published in the Department's Annual Report, also reprinted in papers circulating in the main agricultural districts.

Research : Quadrat investigations on the effect of various forms of management on the botanical composition of western pastures.

OBJECT : To determine effects of (a) cleared and cultivated, (b) cleared and uncultivated, (c) uncleared and uncultivated pasture management on the botanical composition of western pastures.

PROCEDURE : Quadrats are located in each paddock and observations are made from time to time on the botanical covering of the areas. Paddocks are stocked with sheep.

DEPARTMENT : New South Wales, Department of Agriculture.

INVESTIGATORS : J. N. Whittet and A. W. S. Moodie.

LOCATION : Nyngan Experiment Farm.

RESULTS: Uncleared and uncultivated pasture management gives best results. Sections (a) and (b) indicate that indiscriminate clearing results in the formation of windswept plain country; this is accentuated where, in addition, the land is cultivated. The picking up of all small timber is a mistake, as this material lying on the ground provides cover in which grass seed is held and readily germinates; useful native, drought-resistant species of *Panicum*, *Chloris*, *Tragus*, *Andropogon* and *Danthonia*, together with *Erodium* and *Medicago*, ultimately become established and a valuable pasture results.

Research: Pasture improvement in the dairying districts of Southern Victoria.

OBJECT: An investigation into the value of various species and strains of pasture plants, manurial requirements of the soil, and cultural and grazing treatment of the pastures of these areas.

PROCEDURE: The establishment of experimental plots at 46 centres in the southern districts of Victoria. The investigations at 11 centres include: (a) rotational grazing experiments; (b) quantitative manurial mowing trials; (c) trials to determine the most suitable pasture mixtures; (d) trials with various species of grasses and clovers: and at 35 centres the work includes manurial trials and pasture mixture trials.

DEPARTMENT: Victoria, Department of Agriculture.

INVESTIGATORS: J. Brake, B.Agr.Sc., R. L. Twentyman, B.Agr.Sc., J. E. Harrison, B.Agr.Sc. and Assistant Agrostologists.

CO-OPERATION: The Victorian Pasture Improvement League.

LOCATION: At 46 centres in the southern districts of Victoria.

RESULTS: See "Pasture Improvement: A Summary of a Progress Report on the Investigations initiated in 1932 by the Department of Agriculture in co-operation with the Victorian Pasture Improvement League." Jour. Dept. Agr. Vict. Vol. 31, pp. 235-237, 1933.

Research: Testing fodder plants.

OBJECT: A determination of the most suitable fodder plants for different districts of the wheat belt.

PROCEDURE: General observations on the growth and suitability of the respective plots of fodders under test.

DEPARTMENT: Western Australia, Department of Agriculture.

INVESTIGATORS: G. L. Sutton, I. Thomas and E. J. Limbourn.

LOCATION: Chapman and Merredin Government Experiment Farms.

RESULTS: In progress. Results published in the Jour. Dept. Agr. W.A. The results indicate Wimmera ryegrass as the most outstanding fodder. They also indicate the value of burr trefoil and cluster clover for all parts of the wheat belt, and snail clover as the best growing clover in the eastern districts, apart from its inability to persist under grazing conditions. Veldt grass and lupins have shown to advantage on light land receiving a good rainfall.

Research: The establishment and management of seeded pastures.

OBJECT: An investigation of species and strains of pasture plants in relation to establishment, yield, drought resistance and persistency under grazing. An investigation of competition in seeded pastures and the management and manuring of seeded pastures.

DEPARTMENT: Waite Agricultural Research Institute.

INVESTIGATORS: Professor A. E. V. Richardson, M.A., D.Sc., H. C. Trumble, M.Agr.Sc., J. G. Davies, B.Sc., Ph.D., E. A. Cornish, K. A. Pike, and H. P. C. Gallus, B.Sc.

CO-OPERATION: Empire Marketing Board; Council for Scientific and Industrial Research; South Australia, Department of Agriculture and H. W. Morphet and Co.

LOCATION: Glen Osmond, Kybybolite and Woods Point, South Australia.

RESULTS: See (1) "The Role of Pasture Species in Regions of Winter Rainfall and Summer Drought" by H. C. Trumble, M.Agr.Sc., and J. G. Davies, B.Sc., Ph.D. Jour. Coun. Sci. and Ind. Res. Vol. 4, p. 140, 1930.

- (2) "The Taxonomic and Agricultural Characters of the *Danthonia* Group" by A. B. Cashmore, B.Sc., C.S.I.R. Bull. No. 69, 1932.
- (3) "Comparison of *Lolium perenne* and *Phalaris tuberosa* at Varying Stages of Growth" by A. B. Cashmore, B.Sc. (unpublished).
- (4) "The Improvement of *Phalaris* species by Selective Breeding" by H. C. Trumble, M.Agr. Sc. Imperial Bureau of Plant Genetics, Herbage Plants, Bull. No. 7, pp. 18-21, 1932.
- (5) "Preliminary Investigation of Indigenous Saltbushes (*Atriplex*) in an Area of Winter Rainfall and Summer Drought" by H. C. Trumble, M.Agr.Sc. Jour. Coun. Sci. and Ind. Res. Vol. 5, pp. 152-161. 1932.
- (6) "Yield and Botanical Composition of an Irrigated Permanent Pasture under Various Systems of Pasture Management" by A. E. V. Richardson, M.A., D.Sc. In C.S.I.R. Bull. No. 71, "Investigations on Irrigated Pastures, 1932."
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Research : Optimum depths for planting native and introduced pasture grass seeds and also lucerne and clover seeds.

OBJECT : Determination of correct depths at which these seeds should be planted.

PROCEDURE : Pot tests are conducted to obtain these results.

DEPARTMENT : New South Wales, Department of Agriculture.

INVESTIGATORS : J. N. Whittet and A. W. S. Moodie.

LOCATION : Botanic Gardens, Sydney.

RESULTS : All pasture plants (including lucerne) having small seeds are liable to give faulty germination if buried deeply. Seeds of this type require to be lightly covered by planting them not more than $\frac{1}{2}$ -in. below the surface of the soil.

Research : To ascertain if high-fertility-demanding grasses can be established on soils after the fertility has been built up by growing subterranean clover.

OBJECT : To determine the value of subterranean clover in building up soil fertility.

PROCEDURE : Subterranean clover is grown for a number of years and species such as perennial ryegrass, *Phalaris tuberosa*, and cocksfoot are then sown. Soil and pasture analyses are being made of subterranean clover areas and also of natural pasture areas as controls.

DEPARTMENT : New South Wales, Department of Agriculture, Agrostological Branch.

INVESTIGATORS : J. N. Whittet and E. L. Griffiths, B.Sc.

CO-OPERATION : Mr. C. E. Prell, of "Gundowringa," Crookwell, N.S.W.

LOCATION : Crookwell, N.S.W.

Research : Pasture improvement in lighter rainfall areas.

OBJECT : To improve the carrying capacity of pastures in lighter rainfall areas by topdressing and sowing down more suitable species (rainfall mainly 20 to 25 in.).

PROCEDURE : Strips of pasture are topdressed regularly and measurements made of yield, botanical composition, etc. Tests conducted to determine suitability of various pasture species. Carrying capacity (at some centres) determined by means of sheep.

DEPARTMENT : Victoria, Department of Agriculture.

INVESTIGATORS : J. Brake, B.Agr.Sc., and officers of Field Branch.

LOCATION : Experiment Farm, Rutherglen, State Research Farm, Werribee ; Bannockburn, Benalla, Kyneton, Kilmore, Warncoort, Ballarat, Balmoral.

RESULTS : Published in Guide Books to State Farms and in Jour. Dept. Agr. Vict.

Research : Pasture experiments—nitrogenous manuring.

OBJECT : To determine response of dry pastures in dairying districts to nitrogenous manures.

PROCEDURE : Nitrogenous manures applied at regular intervals throughout the year to pasture plots treated with basal dressings of superphosphate. Responses measured by means of mowing and weighing. Resultant changes in botanical composition recorded.

DEPARTMENT : Victoria, Department of Agriculture.

INVESTIGATORS : R. L. Twentyman, B.Agr.Sc., and F. S. Crawford.

LOCATION : At Darnum, Warragul and Colac.

Research : The suitability of various grasses and clovers for wet situations.

OBJECT : To increase the productiveness of areas which are inundated by water for long or short periods of time.

DEPARTMENT : New South Wales, Department of Agriculture.

INVESTIGATORS : Agrostological Branch.

LOCATION : New South Wales generally.

RESULTS : In the coastal districts of northern New South Wales, *Panicum muticum* (*P. barbinode*) has produced satisfactory results under wet swampy conditions.

In the central and south coastal areas, *Panicum distichum*, *Lotus major* and *Trifolium fragiferum* are the best species to plant on wet areas.

(ii) ARID PASTURES.**Research : Arid pasture regeneration—Bluebush and Saltbush (*Kochia* and *Atriplex* spp.).**

PROCEDURE : Standard ecological methods.

DEPARTMENT : University of Adelaide, Department of Botany.

INVESTIGATORS : J. G. Wood, Ph.D., M.Sc., and senior students. (Up till June, 1931, with Professor T. G. B. Osborn, D.Sc., and T. B. Paltridge, B.Sc.)

LOCATION : Koonamore Vegetation Reserve, Koonamore, S.A.

RESULTS : See "On the Growth and Reaction to Grazing of the Perennial Saltbush, *Atriplex vesicarium*.—An Ecological Study of the Biotic Factor" by T. G. B. Osborn, D.Sc., J. G. Wood, Ph.D., M.Sc., and T. B. Paltridge, B.Sc., Proc. Linn. Soc. N.S.W. 57, pp. 377-402, 1932.

Research : Arid flora regeneration (trees and shrubs).

OBJECT : Regeneration of mulga (*Acacia aneura*), Sandelwood (*Myoporum platycarpum*) and leguminous shrubs.

PROCEDURE : Various treatments (firing, etc.) under conditions of rigid enclosure.

DEPARTMENT : University of Adelaide, Department of Botany.

INVESTIGATORS : J. G. Wood, Ph.D., M.Sc., and students.

LOCATION : Koonamore Vegetation Reserve, Koonamore, S.A.

RESULTS : None published as yet. Depredations of rabbits and continued droughts have delayed the work.

Research : Autecology of plants of arid pastoral areas.

OBJECT : Study of growth habits, etc., of arid pasture plants.

PROCEDURE : Standard ecological methods.

DEPARTMENT : University of Adelaide, Department of Botany.

INVESTIGATORS : J. G. Wood, Ph.D., M.Sc. (previously with the co-operation of Professor T. G. B. Osborn, D.Sc., and T. B. Paltridge, B.Sc.), now with co-operation of senior students.

LOCATION : Koonamore Vegetation Reserve, Koonamore, S.A.

RESULTS : See "On the Autecology of *Stipa nitida* : A Study of a Fodder Grass in Arid Australia" by T. G. B. Osborn, D.Sc., and J. G. Wood, Ph.D., M.Sc., Proc. Linn. Soc. N.S.W. Vol. 56, pp. 299-324.

(iii) IRRIGATED PASTURES.

Research : Irrigated pasture investigations—Behaviour of pasture species.

OBJECT : To determine the behaviour of constituents of irrigated mixed pastures under varying systems of watering, manuring and grazing.

PROCEDURE : Estimation by means of sampling technique of the botanical composition of irrigated pasture plots subjected to varying rates and frequencies of watering, manurial dressings and rotational systems of grazing.

DEPARTMENT : Victoria, Department of Agriculture.

INVESTIGATORS : L. C. Bartels, B.Agr.Sc., E. T. Beruldsen, B.Sc.(Agr.), and A. Morgan, B.Agr.Sc.

LOCATION : State Research Farm, Werribee.

RESULTS : See (1) "Irrigated Pastures : Rate and Frequency of Watering Tests" by L. C. Bartels, B.Agr.Sc., E. T. Beruldsen, B.Sc.(Agr.) and A. Morgan, B.Agr.Sc. Jour. Dept. Agr. Vict. Vol. 30, pp. 187-206, 1932.

(2) "Irrigated Pastures—Results of Manurial Trials" by L. C. Bartels, B.Agr.Sc., E. T. Beruldsen, B.Sc.(Agr.) and A. Morgan, B.Agr.Sc. *ibid* Vol. 31, pp. 86-100, 1933.

Research : Irrigated pasture investigations—Sampling technique.

OBJECT : To determine the most suitable technique for the measurement of (a) yield, (b) botanical composition, (3) grazing capacity of mixed pastures under irrigation.

PROCEDURE : The study of (a) uniformity trials to indicate the optimum size and number of plots required for estimation of yield ; (b) methods of sampling and the optimum number and size of samples required for estimation of botanical composition ; and (c) the size and number of samples required to indicate the amount of pasture eaten in grazing trials.

DEPARTMENT : Victoria, Department of Agriculture.

INVESTIGATORS : L. C. Bartels, B.Agr.Sc., E. T. Beruldsen, B.Sc.(Agr.) and A. Morgan, B.Agr.Sc.

LOCATION : State Research Farm, Werribee.

RESULTS : See (1) "Sampling Technique as Applied to Irrigated Pasture in Regard to Botanical Composition and Carrying Capacity under Different Grazing Systems" by A. Morgan, B.Agr.Sc. and E. T. Beruldsen, B.Sc. (Agr.) Jour. Dept. Agr. Vict. pp. 36-45, 1931.

(2) "Irrigated Pasture Investigations Experimental Technique" by E. T. Beruldsen, B.Sc. (Agr.) and A. Morgan, B.Agr.Sc. *ibid* Vol. 31, pp. 251-260, 1933.

Research : Establishment and management of various pasture species under irrigation.

OBJECT : To determine the value of some recently introduced species, as well as the better known species of pasture grasses under irrigation.

PROCEDURE : Pure seed areas of the recently introduced species have been planted and also sown in mixtures with the better known species.

DEPARTMENT : New South Wales, Department of Agriculture, Agrostological Branch.

INVESTIGATORS : J. N. Whittet and H. J. Dargin.

LOCATION : Leeton, N.S.W.

Research : Investigations on pastures and lucerne under irrigation.

OBJECT : To determine factors governing production of mixed pastures and lucerne under irrigation.

PROCEDURE : Rate and frequency of watering, fertilizer and grazing tests.

DEPARTMENT : Victoria, Department of Agriculture.

INVESTIGATORS : L. C. Bartels, B.Agr.Sc., and E. T. Beruldsen, B.Sc.(Agr.)

Co-OPERATION : Irrigation Research Committee, Victoria.

LOCATION : State Research Farm, Werribee, and at country centres, Tongala, Cohuna, Mologa and Stanhope.

RESULTS : Published in Guide Book of State Research Farm, Werribee, and from time to time in Jour. Dept. Agr. Vict.

(iv) NATIVE PASTURE REGENERATION.

Research : The re-establishment of useful native grasses :

- (a) on areas which have been denuded of these grasses,
- (b) on poor quality sandy heath country in the coastal districts of New South Wales.

OBJECT : To increase the carrying capacity and productivity of western pastures by the re-establishment of the useful native grasses and to endeavour to convert unproductive sandy wastes into fair quality grazing land.

DEPARTMENT : New South Wales, Department of Agriculture.

INVESTIGATORS : Agrostological Branch.

LOCATION : New South Wales.

RESULTS : Results which have been obtained in both parts : (a) and (b) of these investigations are as follows :

- (a) Dividing the drier parts of the State up as follows, the most satisfactory species for this work are

- (1) North Western slopes and North Western plains—

- (i) On black soil plain areas :—

Astrebula lappacea, *A. elymoides* and *A. squarrosa* ; *Stipa aristiglumis*, *Iseilema membranacea*, *Paspalidium globoideum* ; *Panicum decompositum*, *P. effusum*, *P. antidotale* and *P. prolutum* ; *Dichantheum sericeum*, *Eriochloa pseudacrotricha*, *Themeda australis*, *Eulalia fulva*, *Chloris truncata*, *Amphilophis intermedia*, *Danthonia pilosa* and *D. semiannularis*.

- (ii) On red soil areas :—

Chloris truncata, *Eriochloa pseudacrotricha* ; *Panicum decompositum*, *P. antidotale* and *P. prolutum* ; *Danthonia pilosa* and *D. semiannularis* ;

- (2) Riverina—same as 1(ii) and *Panicum effusum*.

- (3) Central Western Plains—same as (2).

- (4) Western Division—*Danthonia semiannularis* and *D. pilosa* ; *Chloris truncata*, *Panicum decompositum*, *Dichantheum sericeum*, *Stipa* spp. *Eleusine aegyptica* (in parts).

(b) Carpet grass (*Paspalum compressum*) being only a low fertility demander has been found to thrive on the poor quality sandy heath country in the coastal districts of New South Wales. It continues to give satisfactory results over this type of country but where the species is encroaching on *Paspalum dilatatum* areas it is crowding out the latter species with the consequence that the carrying capacity and productivity of these areas are reduced.

Research : Top-dressing of natural pastures.

OBJECT : To ascertain the effect of applying phosphate on the yield, botanical succession, nutritive value and productivity of natural pastures in phosphate deficient areas.

DEPARTMENT : Waite Agricultural Research Institute.

INVESTIGATORS : H. C. Trumble, M.Agr.Sc., J. G. Davies, B.Sc., Ph.D., K. M. Fraser, B.Agr.Sc., and A. E. Scott, M.Sc.

CO-OPERATION : Empire Marketing Board ; Council for Scientific and Industrial Research ; South Australia, Department of Agriculture.

LOCATION : Glen Osmond and Kybybolite, South Australia.

RESULTS : See (1) " The Effect of Top-dressing with Artificial Fertilizers on the Yield, Botanical Composition and Carrying Capacity of a Natural Pasture " by H. C. Trumble, M.Agr.Sc. and K. M. Fraser, B.Agr.Sc. Jour. Dept. Agr. S.A. Vol 35, p. 1341, 1932.

(2) " The Effect of Superphosphate on Natural Pasture in a Phosphate-deficient Region " by J. G. Davies, B.Sc., Ph.D. and A. E. Scott, M.Sc. (unpublished).

(3) " The Influence of Frequency of Cutting on Natural Pasture in Southern Australia " by J. G. Davies, B.Sc., Ph.D. and A. K. Sim, B.Sc., B.Agr.Sc. C.S.I.R. Pamph. No. 18.

(4) " The Rate of Growth of a South Australian Merino Fleece " by K. M. Fraser, B.Agr.Sc. Jour. Coun. Sci. and Ind. Res. Vol. 4, p. 204, 1931.

Research : Improvement of germinating capabilities of the seed of useful native grasses, especially the genera *Panicum*, *Danthonia*, *Andropogon* and *Chloris*.

OBJECT : Many species of these grasses are difficult to establish in the field, and experiments have been devised to try and obtain satisfactory germination when seed is sown.

PROCEDURE : Treatments with various chemical solutions and other materials have been used in order to facilitate rapid germination.

DEPARTMENT : New South Wales, Department of Agriculture.

INVESTIGATORS : J. N. Whittet, A. W. S. Moodie, Miss J. Hales and Miss A. Myers.

LOCATION : Botanic Gardens, Sydney.

RESULTS : Although a considerable amount of research has been conducted on this matter, no chemical treatment has given satisfactory results. Best results have been obtained where seed has been stored for three or four years before being planted.

Research : Native pastures—Effects of the use of fertilizers on the botanical composition of native pastures.

OBJECT : To determine the effect of fertilizers on the growth and chemical composition of the plants.

PROCEDURE : Pastures are top-dressed at various times of the year with simple and mixed fertilizers.

DEPARTMENT : New South Wales, Department of Agriculture.

INVESTIGATORS : J. N. Whittet and A. W. S. Moodie.

LOCATION : Trangie, Temora, Glen Innes Experimental Farms ; Milvale, Parkes, Milbrulong Farmers' Holdings.

RESULTS : See "Comparative Grazing Trials on Top-dressed Pastures—Three Years' Results at Milvale and Milbrulong" Agr. Gaz. N.S.W. Vol. 41, pp. 11-16, 1930.

3. PASTURE PLANTS.

(i) GENERAL PROBLEMS.

Research : Mineral content of pasture plants.

OBJECT : An investigation of the factors affecting the mineral content and nutritive value of pasture plants, with particular reference to species, stage of growth, soil fertility and climate.

DEPARTMENT : Waite Agricultural Research Institute.

INVESTIGATORS : Professor A. E. V. Richardson, M.A., D.Sc., H. C. Trumble, M.Agr.Sc., J. G. Davies, B.Sc., Ph.D., K. M. Fraser, B.Agr.Sc., A. E. Scott, M.Sc., H. P. C. Gallus, B.Sc., and R. E. Shapter, A.A.I.C.

CO-OPERATION : Empire Marketing Board ; Council for Scientific and Industrial Research.

LOCATION : Glen Osmond, South Australia.

RESULTS : See (1) "The Mineral Content of Pastures" by A. E. V. Richardson, M.A., D.Sc., C.S.I.R. Pamph. No. 17, 1930.

(2) "Factors Affecting the Mineral Content of Pastures, with Particular Reference to the Environmental Conditions Incidental to Southern Australia" by A. E. V. Richardson, M.A., D.Sc., H. C. Trumble, M.Agr.Sc. and R. E. Shapter, A.A.I.C. C.S.I.R. Bull. No. 49, 1931.

(3) "The Effect of Growth Stage and Intensities of Cutting on the Yield and Composition of a Perennial Grass, *Phalaris tuberosa*" by A. E. V. Richardson, M.A., D.Sc., H. C. Trumble, M.Agr.Sc. and R. E. Shapter, A.A.I.C. C.S.I.R. Bull. No. 66, 1932.

(4) "Investigations on the Mineral Content of Pastures" by J. G. Davies, B.Sc., Ph.D., A. E. Scott, M.Sc. and K. M. Fraser, B.Agr.Sc. (unpublished).

(5) "Composition of Pasture Species from Various Regions of Australia" by A. E. Scott, M.Sc. (unpublished).

(6) "The Nitrogen and Phosphoric Acid Content of Twenty Species of Pasture Plants at Fixed Growth Stages" by R. E. Shapter, A.A.I.C. (unpublished).

(7) "The Protein and Phosphoric Acid Content of Sown Pasture subject to Varying Systems of Pasture Management" by H. P. C. Gallus, B.Sc. (unpublished).

Research : The chemical composition of dominant pasture plants.

OBJECT : To determine the fodder value of the principal pasture plants found growing in various districts of New South Wales.

PROCEDURE : The material is collected and analysed. History of area and fertilizer treatments, etc. are recorded.

DEPARTMENT : New South Wales, Department of Agriculture, Agrostological Branch.

INVESTIGATORS : J. N. Whittet and C. E. Ahrens, B.Sc.Agr.

LOCATION : Various localities in New South Wales.

Research : Value of hard seeds, particularly with reference to those of lupins, subterranean clover and white Dutch clover.

OBJECT : To ascertain the real value of hard seeds and incidentally to determine the period they may take to germinate from the time of planting.

PROCEDURE : Samples of seeds are germinated, germination recorded and the hard seeds then planted or placed under suitable conditions for germination. The times taken for germination are recorded and the condition of the seedlings are noted.

DEPARTMENT : Western Australia, Department of Agriculture.

INVESTIGATOR : H. G. Elliott.

LOCATION : Perth.

RESULTS : See "Seed Scarifying Experiments with Locally-grown Legumes" by T. C. Dunne and H. G. Elliott, Jour. Dept. Agr. W. A. Vol. 9, p. 241, 1932.

Research : Influence of fertilizers and/or lime on the chemical composition of pasture plants.

OBJECT : To determine the effect of fertilizers and/or lime on the feeding value of various pasture plants.

PROCEDURE : Material from localities variously treated is collected and analysed.

DEPARTMENT : New South Wales, Department of Agriculture, Agrostological Branch.

INVESTIGATORS : J. N. Whittet, A. W. S. Moodie, and C. E. Ahrens, B.Sc. Agr.

LOCATION : Various localities in New South Wales.

Research : The effect of fertilizers on the germination of seed.

OBJECT : To determine the effect of superphosphate on various pasture plant seeds by mixing seed and fertilizer prior to sowing.

DEPARTMENT : New South Wales, Department of Agriculture, Agrostological Branch.

INVESTIGATORS : J. N. Whittet, and A. W. S. Moodie.

LOCATION : Botanical Gardens, Sydney.

RESULTS : See "Lime and Phosphoric Acid Content of Lucerne as Influenced by the Application of Superphosphate" by A. A. Ramsay and E. L. Griffiths, B.Sc.

Research : Strain investigation with annual pasture plants, Wimmera ryegrass and subterranean clover.

OBJECT : (a) To distinguish and develop strains of these plants suited to Victorian conditions, and (b) to promote seed production.

PROCEDURE : Single plant and broadcast plot studies for botanical and vegetative characteristics ; classification of strains ; country trials to determine most promising strains ; promoting seed production by farmers.

DEPARTMENT : Victoria, Department of Agriculture.

INVESTIGATORS : J. E. Harrison, B.Agr.Sc., F. R. Drake, B.Agr.Sc. and E. D. Cameron, B.Agr.Sc.

LOCATION : Agrostology Branch, Burnley Gardens, Melbourne. Formerly at Experiment Farm, Rutherglen.

RESULTS : Numerous strains of *Trifolium subterraneum* have been isolated and classified. Wimmera ryegrass strains are being bred by isolation, sheltered pollination and multiplication under field conditions.

See (1) "*Lolium subulatum* v. Wimmera Rye Grass" by H. A. Mullett, B.Agr.Sc. Jour. Dept. Agr. Vict. Vol. 17, pp. 266-278, 1919.

(2) "Hard Seeds in subterranean clover" by J. E. Harrison, *ibid* Vol. 29, pp. 287-288, 1931.

(3) "Rye Grasses—Species and Types" by F. R. Drake, B.Agr.Sc. *ibid* Vol. 29, pp. 573-577, 1931.

(4) "Pasture Plant Research" by J. E. Harrison, B.Agr.Sc. *ibid* Vol. 30, pp. 505-511, 1932.

Research : Strain investigation with perennial pasture plants.

OBJECT : (a) To distinguish and develop strains of perennial pasture plants suited to Victorian conditions, and
(b) to promote seed production.

PROCEDURE : Collection of specimens, establishing single plant plots and broadcast plots for examination of botanical and vegetative characteristics ; classification of strains ; country trials to determine most promising strains ; promoting seed production by farmers.

DEPARTMENT : Victoria, Department of Agriculture.

INVESTIGATORS : J. E. Harrison, B.Agr.Sc., F. R. Drake, B.Agr.Sc. and E. D. Cameron, B.Agr.Sc.

LOCATION : Agrostology Branch, Burnley Gardens, Melbourne.

RESULTS : See (1) " Pasture Plant Research " by J. E. Harrison, B.Agr.Sc. Jour. Dept. Agr. Vict. Vol. 30, pp. 505-511, 1932.

(2) " Perennial Rye Grass—Strain Investigation in Victoria " by F. R. Drake, B.Agr.Sc. *ibid* Vol. 30, pp. 557-564, 1932.

Also other articles in same volume of Journal.

Research : Selection of pasture strains.

OBJECT : The building up and ultimate distribution of seed of improved pasture strains.

PROCEDURE : The selection and multiplication of plants with desirable characteristics.

DEPARTMENT : South Australia, Department of Agriculture.

INVESTIGATORS : Professor A. J. Perkins, R. C. Scott and L. J. Cook.

CO-OPERATION : Australian Dairy Council, S.A. Branch (financial assistance).

LOCATION : Kybybolite, S.A.

Research : Period of growth of useful pasture plants, weeds, etc., found in various localities of New South Wales.

OBJECT : The estimation of value, longevity and palatability of various pasture plants.

To compile a census of the botanical composition of pastures in the principal districts of New South Wales.

PROCEDURE : Records obtained during visits to country districts. Notes on grasses, etc., which can be incorporated in the pastures are also made.

DEPARTMENT : New South Wales, Department of Agriculture.

INVESTIGATOR : J. N. Whittet.

LOCATION : All districts of New South Wales.

RESULTS : The census has not yet been compiled ; the records have been collected and when time permits this work will be completed.

Research : The detailed study of various introduced grasses.

OBJECT : To obtain available data as to their pastoral and economic worth.

PROCEDURE : Some 12 promising grasses are being studied under such general headings as history, classification, nomenclature, etc. morphological characters, physiological characters, seed germination, growth studies, life history, ecology and chemistry.

DEPARTMENT : Council for Scientific and Industrial Research, Division of Plant Industry.

INVESTIGATORS : T. B. Paltridge, B.Sc. and H. K. C. Mair, B.Sc.

LOCATION : Canberra (Black Mountain and Duntroon areas).

RESULTS : A method of measuring the relative drought-resisting ability, based on Maximov's observations concerning moisture content in relation to wilting point, has been applied with apparently encouraging results.

Research : Investigational work with species of pasture plants new to Australia.

OBJECT : To obtain drought-resistant pasture plants, winter grasses, suitable legumes, etc. for Australian conditions.

DEPARTMENT : New South Wales, Department of Agriculture.

INVESTIGATORS : Agrostological Branch.

RESULTS : Although a number of these plants has proved drought-resistant, they have failed to produce fertile seed and therefore are of very limited value in the drier parts of the State.

Of winter grasses *Bromus marginatus* is showing to advantage under irrigation, and in coastal and tableland areas.

Although a number of pasture legumes has been introduced no outstanding results have been obtained from them.

(ii) CLOVERS (SPECIAL VARIETIES).

Research : Seeding experiment with subterranean clover.

OBJECT : To determine the effect upon the subsequent growth of subterranean clover of (a) the rate of seeding, (b) the inoculation of the seed, and (c) the covering of the seed.

PROCEDURE :

	Not inoculated.	Inoculated.	
Super-phosphate at rate of 2 cwt. per acre.	1. 2 lb. per acre	1a as for 1	Plots broadcast and planted in duplicate. Each plot one drill-width wide 1/16th acre in area.
	2. 8 lb. (control)	2a " " 2	
	3. 4 lb. per acre.	3a " " 3	
	4. 16 lb. per acre	4a " " 4	
	5. 8 lb. (control)	5a " " 5	
	6. 8 lb. (not covered)	6a " " 6	

DEPARTMENT : Western Australia, Department of Agriculture.

INVESTIGATORS : T. C. Dunne, I. Thomas, A. Venton and D. R. Bateman.

LOCATION : Light Lands Farm, Wongan Hills, W.A.

Research : Trial with snail clover.

OBJECT : To test the suitability of snail clover [*Medicago scutellata*] as a fodder plant.

PROCEDURE : A small quantity of snail clover (in burr) was planted at several experiment farms (shown here-under).

DEPARTMENT : Western Australia, Department of Agriculture.

INVESTIGATORS : C. A. Gardner, I. Thomas and K. T. Lutz, B.Sc. (Agr.)

LOCATION : Merredin, Chapman, Wongan Hills, Yilgarn and Salmon Gums Government Experiment Farms.

RESULTS : In drier portions of wheat belt snail clover makes better growth than the annual clovers and trefoils, but does not persist under grazing conditions.

(iii) GRASSES (SPECIAL VARIETIES).

Research : Lolium perenne—Survey and determination of the various New South Wales regional strains.

OBJECT : To determine by comparative tests the value of New South Wales regional strains using New Zealand certified *Lolium perenne* as controls.

PROCEDURE : Areas are sown for cutting and weighing and the most promising strains are then tested out under grazing conditions.

DEPARTMENT : New South Wales, Department of Agriculture, Agrostological Branch.

INVESTIGATORS : J. N. Whittet, A. W. S. Moodie and A. L. Clothier.

LOCATION : Glen Innes and Berry, N.S.W.

Research : Causes of the deterioration of Paspalum dilatatum pastures.

OBJECT : To conduct investigations in the matter of renovating *Paspalum* pastures.

PROCEDURE : Various implements have been tried, simple and mixed fertilizers used, and winter and summer grasses and legumes incorporated with the *Paspalum*.

DEPARTMENT : New South Wales, Department of Agriculture.

INVESTIGATORS : J. N. Whittet, A. W. S. Moodie, and M. J. E. Squire,

LOCATION: Wollongbar Experiment Farm, Lismore, Murwillumbah, Bangalow, Mullumbimby, Dorrigo, Coramba and eight other centres.

RESULTS: It has been recorded in the Agricultural Gazette at various times during the last three years that it is unwise to apply artificial fertilizers to *Paspalum* pastures unless the areas have been previously renovated with special *Paspalum* cultivators or *Paspalum* harrows. Further details of implements used, fertilizers applied and grass mixture recommended have been recorded in recent issues of the Agricultural Gazette of New South Wales.

Research: To determine the suitability of *Spartina townsendii* for tropical and semi-tropical conditions.

OBJECT: To devise a means of reclaiming marine mud flats.

PROCEDURE: Experimental plantings at various points along the coast.

DEPARTMENT: Queensland, Department of Agriculture and Stock.

INVESTIGATORS: G. B. Brooks and C. S. Clydesdale.

LOCATION: Brisbane, Gladstone and Rockhampton.

Research: Studies of *Themeda australis* (Kangaroo Grass.)

OBJECT: Kangaroo grass, unlike *Danthonia* spp. tends to disappear when continuously grazed. By a study of the morphological and other characters and general behaviour of this grass an endeavour is being made to determine the precise cause for such disappearance, and, if possible, how it may be overcome.

DEPARTMENT: Council for Scientific and Industrial Research, Division of Plant Industry.

INVESTIGATOR: H. K. C. Mair, B.Sc.

LOCATION: Canberra.

RESULTS: Studies of seed germination, flowering and pollination, seedling morphology, and the effects of continuous grazing by sheep and cattle, respectively, have been made and are being continued.

4. TECHNIQUE OF GRASSLAND INVESTIGATIONS.

Research: Investigation of grassland technique.

OBJECT: To determine suitable methods of determining grassland investigations.

DEPARTMENT: Waite Agricultural Research Institute.

INVESTIGATORS: Professor A. E. V. Richardson, M.A., D.Sc., H. C. Trumble, M.Agr.Sc., and J. G. Davies, B.Sc., Ph.D.

LOCATION: Glen Osmond, South Australia.

RESULTS: See "The Experimental Error of the Yield from Small Plots of National Pasture," by J. G. Davies, B.Sc., Ph.D., C.S.I.R. Bull. No. 48, 1930.

GENETICS AND PLANT BREEDING—FIELD CROPS AND PASTURE PLANTS.

GRASSES.

Research: Perennial strains of Wimmera ryegrass.

OBJECT: The development of free-seeding perennial strains of Wimmera ryegrass for dry localities.

DEPARTMENT: New South Wales, Department of Agriculture, Plant Breeding Branch.

INVESTIGATORS: Staff of Plant Breeding Branch.

RESULTS: Supplies of seed have been raised and distributed to farmers and graziers in this and other States. Further selection work is now being conducted with these strains in an endeavour to develop drought-resistant, free-seeding, perennial types.

Research : Grass and clover improvement.

OBJECT : To evolve improved strains of the commercially grown species.

PROCEDURE : Selection and line breeding.

DEPARTMENT : New South Wales, Department of Agriculture, Plant Breeding Branch.

INVESTIGATORS : Staff of Plant Breeding Branch.

LOCATION : Chiefly coastal and Tableland Experiment Farms of New South Wales.

FIELD CROPS—CULTURAL PROBLEMS.**LUCERNE.****Research : Chemical composition of lucerne at various stages of growth.**

OBJECT : To determine the optimum stage at which to graze sheep or cattle on lucerne.

PROCEDURE : The material is cut at various stages and chemical analyses made.

DEPARTMENT : New South Wales, Department of Agriculture, Agrostological Branch.

INVESTIGATORS : E. L. Griffiths, B.Sc., J. N. Whittet and various Departmental experimentalists.

LOCATION : Cowra and Trangie.

RESULTS : See "Lucerne Cut at Various Stages of Growth : An Investigation as to its comparison and Yield," by E. Griffiths, B.Sc., and A. A. Ramsay, F.C.S., F.A.I.C. Agr. Gaz. N.S.W. Vol. 43, pp. 657-667, 1932.

Research : A survey of the pH value of lucerne soils.

OBJECT : To determine the toleration of lucerne to soil acidity.

PROCEDURE : Soil samples are taken from established lucerne areas and tested for pH value.

DEPARTMENT : New South Wales, Department of Agriculture, Agrostological Branch.

INVESTIGATORS : E. L. Griffiths, B.Sc., Chemist, J. N. Whittet, and A. W. S. Moodie.

LOCATION : Various parts of New South Wales.

Research : The effect of establishing lucerne with a wheat crop as compared with lucerne sown without wheat.

OBJECT : To determine the effect of the cereal crop on the subsequent establishment of lucerne in the comparatively drier parts of New South Wales.

PROCEDURE : Various rates of seeding of both cereal and legume are compared with similar rates of the legume sown without the cereal.

DEPARTMENT : New South Wales, Department of Agriculture, Agrostological Branch.

INVESTIGATORS : J. N. Whittet, A. W. S. Moodie and various other experimentalists.

LOCATION : Cowra, Bathurst and Trangie.

Research : The adaptability of lucerne for grazing purposes in comparatively dry and cold localities.

OBJECT : To encourage the growing of lucerne as a grazing proposition.

DEPARTMENT : New South Wales, Department of Agriculture, Agrostological Branch.

INVESTIGATORS : J. N. Whittet and other officers of the Branch.

RESULTS : During the past five years extensive areas of lucerne have been established in the drier districts of the State and also in cold localities. Most convincing results have been obtained from the use of light seedings of 2-3 lbs. per acre for grazing purposes, and graziers who formerly planted 10-12 lbs. per acre are now adopting the Department's recommendations re light seeding.

See reports published in the Agr. Gaz. N.S.W.

Research : Effect of fertilizers on the chemical composition of lucerne.

OBJECT : To determine the effect of superphosphate on the feeding value of lucerne.

PROCEDURE : Material is cut at various stages of growth and chemical analyses are made.

DEPARTMENT : New South Wales, Department of Agriculture, Agrostological Branch.

INVESTIGATORS : E. L. Griffiths, B.Sc., J. N. Whittet and various experimentalists.

LOCATION : Richmond, Grafton and Cowra.

Research : Establishment of lucerne for crossing purposes without prior soil treatment.

OBJECT : To determine whether lucerne can be established on self-mulching soils without any prior preparation such as ploughing or cultivating.

PROCEDURE : Seed is scattered over the land and allowed to be tramped in by sheep, or it is harrowed in.

DEPARTMENT : New South Wales, Department of Agriculture, Agrostological Branch.

INVESTIGATORS : J. N. Whittet and A. W. S. Moodie.

LOCATION : Various localities in New South Wales.

Research : Lucerne seed setting investigations.

OBJECT : To determine the effect of environment and the role played by insects in seed setting in lucerne.

PROCEDURE : Close observations under field and laboratory conditions.

DEPARTMENT : New South Wales, Department of Agriculture, Plant Breeding Branch.

INVESTIGATORS : R. E. Dwyer, B.Sc.Agr., Assistant Plant Breeder, and S. L. Allman, M.Sc., B.Sc.Agr., Assistant Entomologist, Bathurst Experiment Farm.

LOCATION : Bathurst Experiment Farm.

RESULTS : Some results have been published in the Agr. Gaz. N.S.W.

LUPINS.**Research : The effect of different seed treatments to increase the germination capacity of lupin seeds.**

OBJECT : To ascertain the most practical methods of reducing the percentage of "hard" seeds and consequently increasing the germinating capacity of lupin seeds.

PROCEDURE : Selected seeds of the West Australian grown "Blue" lupin, new season seeds, are treated in various ways, to increase the germinating capacity and reduce the hard seeds, without affecting the good germinable seeds. The treated lots will be tested in the laboratory and also under field conditions in pots.

Control tests to ascertain germinating capacity before treatment will be carried out for each sample.

DEPARTMENT : Western Australia, Department of Agriculture.

INVESTIGATOR : H. G. Elliott.

LOCATION : Government Gardens, Perth, and the Plant Pathology Laboratory.

RESULTS : (a) Seed planted in boxes is still showing germination after three years. Over the first six months 52 per cent germination occurred. From then onwards spasmodic germination has occurred at various intervals following seasonal rains. Total germination in three years, 81 per cent with 16 per cent of seeds still unaffected by climatic conditions.

(b) Experiments show that harvested seed has a higher percentage of hard seeds than seed allowed to fall and later gathered from the ground. In all trials both harvested and collected seeds were taken from the same field.

(c) In all experiments chipped seed gave the best germination.

(d) Hot water treatment : In this experiment it was found that the highest germination was obtained by putting the seed in cold water and heating to 70°C. and holding at that temperature for 15 minutes cooling and air drying. The resulting increase in germination was 180 per cent.

(e) Dry heat : Best results obtain by heating to 100°C. and holding for 10 minutes. The increase in germination over the non-heated seed was 60 per cent.

PLANT DISEASES.

GRASSES.

Research : Foot-rot—the rôle of grasses in the spread and perennation of the organisms causing take-all and foot-rots of wheat.

OBJECT : To investigate the importance of grasses as possible factors in increasing losses due to take-all and foot-rots, and to find pasture grasses which are unaffected by the foot-rot organisms, and which are suitable for wheat-growing areas.

PROCEDURE : Collections of naturally-occurring diseased grasses are made wherever possible, and the organisms responsible are isolated from them. As many grasses as possible are tested for susceptibility to the foot-rot organisms.

DEPARTMENT : Council for Scientific and Industrial Research, Division of Plant Industry.

INVESTIGATOR : W. V. Ludbrook, B.Agr.Sc., Ph.D.

LOCATION : Canberra, F.C.T.

RESULTS : *Wojnowicia graminis* has been isolated from naturally diseased *Festuca myuros* and *Hordeum murinum*, *Ophiobolus graminis* from *Agropyron cristatum*, and *Fusarium culmorum* from *F. myuros*.

Research : Foot-rot of Gramineae due to *Wojnowicia graminis*.

OBJECT : To investigate the importance of this organism as compared with the other organisms causing foot-rot, its host range, environmental relations, distribution, and the possibility of remedial or control measures, including a search for resistant varieties of wheat.

PROCEDURE : Cultures of the organism from different parts of the wheat belt have been obtained and examined to determine the range of variability of the organism. Using representative cultures, experiments are being conducted (1) to determine the pathogenicity of the organism to wheat as compared with that of the three other principal foot-rot organisms ; (2) to determine its host range ; at present six cereals and seven grasses are under trial ; (3) to determine the effect of soil moisture and soil temperature on the pathogenicity of the organisms ; (4) to compare the susceptibility of different wheat varieties to the organism ; at present about 140 varieties are being tested in the greenhouse and in the field ; (5) to test the effect of other organisms on the pathogenicity of *W. graminis*.

DEPARTMENT : Council for Scientific and Industrial Research, Division of Plant Industry.

INVESTIGATOR : W. V. Ludbrook, B.Agr.Sc., Ph.D.

LOCATION : Canberra.

RESULTS : The organism has been isolated from naturally-infected *Festuca myuros* and artificially-infected oats. There appear to be two or more strains of the organism, distinguishable by differences in cultural characters. The maximum temperature for growth in culture is about 30°, and the optimum probably about 20-25°.

LUCERNE.

Research : Spindle shoot disease.

OBJECT : (a) A determination of the nature of the disease, and
(b) the development of control measures.

PROCEDURE : Infection tests and field observations.

DEPARTMENT : New South Wales, Department of Agriculture, Plant Pathology Branch.

INVESTIGATOR : E. T. Edwards, B.Sc.Agr.

LOCATION : (a) Sydney, (b) Bathurst.

INSECT AND OTHER PESTS OF PLANTS.

CLOVER SPRINGTAIL OR LUCERNE FLEA.

Research : Clover springtail (*Sminthurus viridis*).

OBJECT : An investigation of the possibility of biological control by a systematic study of the Bdellid mites of Australia as possible predators of the clover springtail.

DEPARTMENT : Council for Scientific and Industrial Research, Division of Economic Entomology.

INVESTIGATOR : H. Womersley.

CO-OPERATION : Department of Agriculture and University of Western Australia ; and Waite Agricultural Research Institute, S.A.

LOCATION : Perth, W.A.

RESULTS : A survey of the incidence of this pest in Western Australia showed that in certain localities it had ceased to be of importance ; in these areas it was found to be attacked by a species of Bdellid mite (*Biscirus lapidarius* Kramer). Further observations have shown that this mite is an effective predator of Sminthurids and demonstrated its possibility as a control. It has been successfully transported to infested areas where it could not previously be found.

Research : Clover springtail or lucerne flea (*Sminthurus viridis* Linn.).

OBJECT : To investigate the practicability of control by chemical means.

DEPARTMENT : Council for Scientific and Industrial Research, Division of Economic Entomology.

INVESTIGATORS : H. Womersley and L. J. Newman.

CO-OPERATION : Western Australia, Department of Agriculture and University ; and Waite Institute, South Australia.

LOCATION : Perth, W.A.

RESULTS : Experiments in W.A. have shown that spraying of infested paddocks with a mixture of lime sulphur at a dilution of 1-60 and at the rate of 80 gallons per acre is effective in reducing the population of *Sminthurus*. Initial spraying must be done within the first week of first winter rains, and, if possible, repeated within two or three weeks.

Research : Clover springtail or lucerne flea.

OBJECT : To investigate methods for the control of lucerne flea.

PROCEDURE : The spraying and dusting of infected areas.

DEPARTMENT : South Australia, Department of Agriculture.

INVESTIGATORS : J. Davidson, D.Sc., G. Quinn and R. C. Scott.

LOCATION : Vicinity of Adelaide, S.A.

RESULTS : Two per cent solution of lime sulphur is effective for some areas. See " On the control of ' lucerne flea ' (*Sminthurus viridis* L.) in lucerne in South Australia " by J. Davidson, D.Sc., Jour. Dept. Agr. S.A. Vol. 36. pp. 994-1006, 1933.

Research : Clover springtail or lucerne flea (*Sminthurus viridis*).

OBJECT : To investigate the cause of the occurrence of this pest in epidemic numbers on pastures and to suggest control measures.

PROCEDURE : Laboratory studies and field experiments.

DEPARTMENT : Waite Agricultural Research Institute.

INVESTIGATORS : J. Davidson, D.Sc., and D. C. Swan.

LOCATION : Glen Osmond, South Australia.

RESULTS : See (1) " The influence of temperature on the incubation period of the eggs of *Sminthurus viridis* L. (Collembola) " by J. Davidson, D.Sc., F.L.S. Aust. Jour. of Expt. Biol. and Med. Sci. Vol. 8, pp. 143-152, 1931.

(2) " Factors affecting oviposition of *Sminthurus viridis* L. (Collembola) " by J. Davidson, D.Sc., F.L.S. *Ibid* Vol. 9, pp. 1-16, 1932.

(3) " On the viability of the eggs of *Sminthurus viridis* L. (Collembola) in relation to their environment " by J. Davidson, D.Sc., F.L.S. *Ibid* Vol. 10, pp. 65-88. 1933.

Research : Clover springtail or lucerne flea.

OBJECT : To determine the life history of the lucerne flea (*Sminthurus viridis*) together with means for the control of the pest in the field and in produce.

PROCEDURE : Laboratory and field experiments in potato crops.

DEPARTMENT : Victoria, Department of Agriculture.

INVESTIGATORS : C. French and R. T. M. Pescott, M.Agr.Sc.

LOCATION : Plant Research Laboratory, Burnley Gardens, Melbourne ; field work at Koroit, Victoria.

GRASS-PESTS—GENERAL.**Research : Grass pests of the Atherton Tableland.**

OBJECT : To devise means for the reduction of losses due to the several species concerned.

PROCEDURE : Life history and environmental studies.

DEPARTMENT : Queensland, Department of Agriculture and Stock, Divisions of Entomology and Plant Pathology.

INVESTIGATOR : D. O. Atherton, B.Sc.

LOCATION : Atherton, North Queensland.

RESULTS : See "Grass pests of the Atherton Tableland" by D. O. Atherton, B.Sc. Q'ld Agr. Jour. Vol. 36, pp. 474-481. 1931.

GRASS GRUB. TASMANIAN.**Research : Tasmanian grass grub.**

OBJECT : Biological methods of control of *Oncopera*.

PROCEDURE : To introduce the Tachinid fly *Protohystricina signata* into Australia from New Zealand, where it is known to be parasitic on the genus *Porina* which is closely allied to *Oncopera*.

DEPARTMENT : Council for Scientific and Industrial Research, Division of Economic Entomology.

INVESTIGATOR : A. L. Tonnoir.

CO-OPERATION : Cawthron Institute, Nelson, N.Z.

LOCATION : Federal Capital Territory and Leongatha, Victoria.

RESULTS : A study of the parasite has been made in New Zealand and several consignments have been sent to Victoria.

LUCERNE PESTS—GENERAL.**Research : Lucerne pests.**

OBJECT : The bionomics and control of insect pests of lucerne causing serious losses in yield of hay and seed.

PROCEDURE : Field and laboratory investigations ; experiments with calcium arsenate and other arsenicals.

It is proposed to test the possible use of aeroplanes in applying arsenical dusts in the larger lucerne-growing districts.

DEPARTMENT : New South Wales, Department of Agriculture, Entomological Branch.

INVESTIGATORS : W. B. Gurney, B.Sc., and T. McCarthy.

LOCATION : Scone, Tamworth, Coolah Valley, etc., N.S.W.

RESULTS : Life history studies of *Heliothis obsoleta* and *Tortrix glaphyriana* have been worked out and partial studies of the life history of *Leptops sinuatus* have been made. Preliminary experiments employing lead arsenate for control of the above-mentioned pests have been completed. Dusted lucerne when fed to stock had no deleterious effect. A first record has been made of an unknown species of Curculionid, the larvae of which are found attacking lucerne roots in a similar manner to *Leptops sinuatus*.

POISON PLANTS.**Research : Poison plants investigations.**

OBJECT : To test suspected plants and determine their harmfulness or otherwise : to conduct further tests of known poison plants.

PROCEDURE : Feeding tests.

DEPARTMENT : New South Wales, Department of Agriculture, Veterinary Research Station.

INVESTIGATORS : Staff of Veterinary Research Station.

CO-OPERATION : Stock Branch and Botanist of Department, Pharmacology and Chemical Departments of Sydney University and Poison Plants Committee of the Council for Scientific and Industrial Research.

LOCATION : Veterinary Research Station, Glenfield, N.S.W., and field.

RESULTS : See N.S.W. Dept. Agr. Vet. Res. Repts. Nos. 1-6, 1923-33.

PLANT INTRODUCTION.

Research : The introduction, testing and distribution for further test of species, varieties and strains of plants new to Australia.

OBJECT : To augment the agricultural, pastoral and horticultural resources of the Commonwealth as a whole.

PROCEDURE : Systematic search for (by correspondence) the introduction, testing in various effective ways, and the distribution for more diversified testing and possible general culture of pasture plants (grasses and legumes) adapted to (1) the winter rainfall areas, (2) the summer rainfall areas (sub-tropical and tropical), and to some extent (3) the areas of good and well-distributed rainfall, and cooler temperatures. The importation, trial and limited distribution of wheats, oats and barleys carrying definite characteristics such as yielding ability, early maturity, drought-resistance, disease-resistance, malting value, etc.

DEPARTMENT : Council for Scientific and Industrial Research, Division of Plant Industry.

INVESTIGATORS : A. McTaggart, B.S.A., M.S.A., Ph.D., and W. Hartley, B.A.

CO-OPERATION : Professor J. K. Murray, B.A., B.Sc.Agr., and W. R. Bryan at Gatton College, Queensland ; and A. W. Turner, D.V.Sc., at Oonoonba, Queensland.

LOCATION : (a) Canberra (Black Mountain and Duntroon areas) F.C.T. ;
(b) Queensland Agricultural College, Gatton, Queensland ;
(c) Provision has been made for certain testing work to be conducted at the Commonwealth Tobacco Station, Mareeba, Queensland ; and at the Animal Health Research Station, Oonoonba, Townsville.

RESULTS : The introduction and testing under quarantine conditions at Canberra and Gatton of :

Wheats	..	..	..	..	..	1014	Forage plants other than grasses and		
Grasses	..	..	..	..	..	686	legumes	..	..
Legumes	..	..	..	..	..	655	Vegetable garden crops	..	..
Miscellaneous plants	..	..	..	..	..	146	Tea plant varieties	..	..
Barleys	..	..	..	..	..	111	Fruit crops	..	..
Maizes	..	..	..	..	..	53	Rubber-producing plants	..	..
Oats	..	..	..	..	..	17	Fibre plants	..	..
							Insecticidal plants	..	..
							Oil-producing plants	..	..

These are briefly described in Plant Introduction Inventories Nos. 1, 2 and 3, issued by the Council to a limited list of collaborators in Australia and abroad. The results, since the work began early in 1930, of the preliminary testing at Canberra and Gatton have been the classifying of some 40 introductions as distinctly promising and of over 200 as promising. A number has already been distributed throughout Australia for more diversified testing, while seed recently harvested will now permit the extension of such work in co-operation with officers of the State Departments of Agriculture and other collaborators. Descriptive matter and results of tests relating to the above are in course of preparation.

PLANT PHYSIOLOGY PROBLEMS.

METABOLISM.

Research : Mineral metabolism of plants.

OBJECT : An investigation of the physiological mechanism of uptake of ions by plants and the relation of mineral ions to various physiological processes in the plant.

PROCEDURE : Glasshouse and laboratory work.

DEPARTMENT : Waite Agricultural Research Institute.

INVESTIGATORS : A. H. K. Petrie, Ph.D., M.Sc., and L. A. T. Ballard.

LOCATION : Glen Osmond, S.A.

RESULTS : See "A Note on the Relation of Mineral Nutrition to Transpiration in Plants," by A. H. K. Petrie, Ph.D., M.Sc. Jour. Coun. Sci. and Ind. Res. Vol. 5. pp. 177-180, 1932.

PHOTOSYNTHESIS.

Research : Photosynthesis of carbon and nitrogen compounds.

OBJECT : To determine (a) the nature of protoplasmic factor in photosynthesis ; (b) the metabolism of nitrogen compounds in saltbush.

PROCEDURE : Standard physiological and biochemical procedure.

DEPARTMENT : University of Adelaide, Department of Botany.

INVESTIGATOR : J. G. Wood, Ph.D., M.Sc.

LOCATION : University of Adelaide.

RESULTS : Paper prepared for publication, but not yet published.

XEROPHYTISM.

Research : Physiology of xerophytism in arid Australian plants.

OBJECT : To study the course of metabolic processes resulting in xeromorphic structure.

PROCEDURE : Standard physiological and biochemical procedure.

DEPARTMENT : University of Adelaide, Department of Botany.

INVESTIGATOR : J. G. Wood, Ph.D., M.Sc.

LOCATION : Koonamore Vegetation Reserve and Department of Botany, University of Adelaide.

RESULTS : See (1) "Carbohydrate Metabolism of Plant with Tomentose Succulent Leaves" by J. G. Wood, Ph.D., M.Sc. Aust. Jour. Expt. Biol. and Med. Sci. Vol. 10, pp. 89-95, 1932.

(2) "Carbohydrate Changes in the Leaves of Sclerophyll Plants" by J. G. Wood, Ph.D., M.Sc. Aust. Jour. Expt. Biol. and Med. Sci. Vol. 11, 139-150, 1933.

WATER REQUIREMENTS.

Research : Water requirements of field crops and pasture plants.

OBJECT : To ascertain the water requirements of standard varieties of the principal field crops, and natural and cultivated pasture plants ; also an investigation of the factors affecting water requirements.

DEPARTMENT : Waite Agricultural Research Institute.

INVESTIGATOR : Professor A. E. V. Richardson, M.A., D.Sc., and H. C. Trumble, M.Agr.Sc.

LOCATION : Glen Osmond, S.A.

RESULTS : See (1) "The Transpiration Ratio of Farm Crops and Pasture Plants in the Adelaide District" by A. E. V. Richardson, M.A., D.Sc., and H. C. Trumble, M.Agr.Sc. Jour. Dept. Agr. S.A. Vol. 32, p. 224. 1928.

(2) "Water Requirements of Pasture Plants in a Region of Winter Rainfall and Summer Drought and the Factors Affecting the Transpiration Efficiency," by A. E. V. Richardson, M.A., D.Sc., and H. C. Trumble, M.Agr.Sc. (unpublished).

(3) "Relation of Mineral Nutrition to Transpiration," by A. K. Petrie, M.Sc., Ph.D. Jour. Coun. Sci. and Ind. Res. Vol. 5. p. 177, 1932.

B.—TECHNIQUE EMPLOYED IN PASTURE
INVESTIGATIONS IN AUSTRALIA.

NOTES ON THE TECHNIQUE OF PASTURE INVESTIGATIONS.

J. GRIFFITHS DAVIES, B.Sc., Ph.D., Agrostologist, and H. C. TRUMBLE, M.Agr.Sc., Agronomist,
Waite Agricultural Research Institute, University of Adelaide.

The Annual Conference of Australian Agrostologists, held in Adelaide in October 1932, requested the authors to indicate the technique adopted by the Waite Agricultural Research Institute in the conduct of pasture investigations. During the Conference a brief outline was communicated. The following paper has been prepared to amplify and supplement the statement then made.

The data required in the course of pasture investigations are divisible into four main sections :—

1. The determination of botanical composition.
2. The determination of the yield of herbage.
3. The determination of productivity in terms of the grazing animal and its products.
4. The determination of chemical composition.

I. THE DETERMINATION OF BOTANICAL COMPOSITION.

In all aspects of pasture investigation a knowledge of the floristic composition of the sward is essential to the full appreciation of the influence of environment and of treatment on the pasture. The determination of the botanical composition has been attempted in several ways, but no one of these methods can be regarded as satisfactory under all conditions.

(a) *Methods of sampling.*

A brief survey of the main methods of botanical analysis has been made by Davies (2), who has also conducted investigations into the question of the adequate sampling of seeds mixture plots for this purpose. He concluded that the most satisfactory size of plot for detailed investigations of swards in Britain was from 1/500th-1/100th acre. The number of replications required was a minimum of five.

For making botanical analyses of the plots under grazing conditions, ten random samples of a 6 × 6 in. mesh were regarded as being suitable.

For sampling hay crops, random "field" samples of approximately 10 lb. green weight per plot were carefully drawn from the cut herbage immediately after mowing. The field sample was then taken to the laboratory, sub-sampled by the method of quartering and a 2 lb. green sample drawn for dry weight estimations. A further sample of 1 lb. green weight, similarly drawn, was found satisfactory for botanical analyses. For pure species plots, the sample for botanical analysis could be reduced to a minimum of 6 oz. green weight.

(b) *Methods of botanical analysis.*

In his survey of the methods used for botanical analysis, Davies has discussed the principal features of the following methods :—

- (1) The percentage frequency method.
- (2) The percentage tiller estimation.
- (3) The percentage area method.
- (4) The point quadrat method.
- (5) The specific frequency method.
- (6) Charting.
- (7) The percentage productivity method.
 - (i) By hand separation and weighing.
 - (ii) By estimation in the laboratory.
 - (iii) By estimation in the field.

The essential points of difference involved are as follows :—

(i) In the choice of the property or characteristic of the species on which the measurement of contribution to the sward is based. The three alternatives are the percentage occurrence of plants or tillers, the percentage of ground covered, and the productivity in terms of weight.

(ii) In the use of actual measurements or of eye-estimation as the means of evaluation.

The methods which have been used most widely are the "percentage frequency method," the "percentage tiller estimation," and the determination of percentage productivity by separation and weighing or by estimation after cutting.

The "point quadrat method" has been used extensively by Bruce Levy in New Zealand.*

Davies, in his survey, concluded that the "percentage frequency method" was too tedious. In this method, the percentage occurrence of each species on a small sample area is calculated. The unit employed is either the single plant or the single tiller, and the counts are generally made on lifted turves. The time required to make the counts was regarded as excessive, and adequate sampling impracticable. The resultant decrease in the number of replications that can be handled greatly detracts from the value of the method.

(c) *Features of methods based on eye-estimation.*

Davies also drew attention to the more rapid "percentage tiller estimation" method for field work, and the "percentage productivity estimation" method for laboratory analysis of cut herbage. The essential feature of both methods is that the investigator makes eye estimates of the contributions of the constituent species. The number of tillers are estimated in the former method, whilst the weight of species is estimated in the latter method. The results are recorded on a basis 0-10, the total tillers being allocated 10 marks, the estimated contribution of each species to the total tillers being allocated a suitable proportion of the ten marks. The estimates are made 10 times at random, and by summation a percentage figure is obtained. In the case of cut herbage, the total sample is divided into 10 approximately equal sub-samples. Each sub-sample is given 10 marks for total weight. The contribution of each species to the total weight of the sub-sample is estimated and a suitable mark given. By summation of ten estimates for each sample a percentage figure is obtained.

It is claimed by Davies that the estimation methods, when carefully used, are considerably more useful than the "percentage frequency method." The rapidity of obtaining the analysis of any one sample results in a greater number of samples being estimated. This increase in replication is held to outweigh the decreased precision of the eye estimate.

The "percentage productivity estimation" on cut herbage has been extensively used at the Waite Institute. It has been found entirely satisfactory for both "natural" and sown pastures. The alternative of hand separation of the constituent species was found impracticable even when the field samples were reduced to the smallest practicable sub-samples. The labour required was found to be excessive in view of the small samples separated.

(d) *Tests of the estimation method.*

To illustrate the variation between estimates of botanical analyses of a field sample, Table 1 is given. A field sample of approximately 150 grams air-dry weight of "natural" pasture was taken. The sample was thoroughly mixed and fifteen 10 gram sub-samples drawn. Each sub-sample was then hand separated into its constituent species and the weight of each species recorded.

*See *Herb. Publ. Ser. Bull.* 11, 1933.

TABLE 1.—Showing the variation in the percentage contribution by weight of the species in a sample of "natural" pasture.

Sub-sample	<i>Dan-thonia.</i>	<i>Erodium.</i>	<i>Echium.</i>	<i>Romulea.</i>	Annual Grass.	<i>Brachypodium.</i>	Legumes.	Misc.	<i>Oxalis.</i>	Dead and Extra.
1	0.1	7.1	0.2	32.0	17.5	31.0	0.7	0.4	3.5	7.1
2	—	7.8	—	35.6	16.9	26.3	0.2	1.2	3.0	7.6
3	T	5.9	1.8	34.0	14.6	28.7	1.4	0.7	3.6	10.3
4	—	7.4	2.3	31.0	19.2	25.1	2.9	—	4.0	5.5
5	0.2	5.3	1.3	35.4	13.6	28.3	1.4	0.6	3.2	8.7
6	—	7.8	1.9	34.3	23.1	24.5	0.2	—	2.1	2.8
7	—	7.7	1.1	32.8	11.4	21.6	0.8	0.3	4.0	18.4
8	—	4.7	1.6	33.2	21.2	25.3	0.6	0.1	3.6	5.5
9	—	7.8	1.5	34.7	22.4	25.2	0.2	—	2.9	3.7
10	T	5.0	2.0	28.9	28.1	27.0	0.1	—	2.6	3.2
11	—	7.0	1.0	28.9	28.1	23.9	0.1	1.0	2.6	3.9
12	0.4	7.6	1.4	31.5	23.3	23.9	0.3	1.0	3.2	3.9
13	0.4	8.4	1.0	28.8	27.7	23.6	0.8	0.8	2.8	2.9
14	0.1	8.7	1.5	28.9	25.3	23.4	0.6	0.5	4.6	4.3
15	—	5.9	1.10	31.0	25.7	26.9	1.0	1.1	2.5	4.0

(All figures as percentages of the sub-sample weight).

In Table 2 are the results of tests of the estimation method conducted during routine analyses in the laboratory. These tests are made at intervals as a check on the eye estimations.

TABLE 2.—Comparisons of the botanical composition of a sample as obtained by (a) the percentage estimation method, (b) the hand separation of 10 gram sub-samples.

Species.	<i>Dan-thonia.</i>	<i>Erodium.</i>	<i>Echium.</i>	<i>Romulea.</i>	Annual Grasses.	<i>Brachypodium.</i>	Legumes.	<i>Trifolium arvense</i>	<i>Oxalis.</i>	Misc.
1 { Hand separation ..	0.0	38.4	8.7	1.4	31.8	3.5	2.1	13.0	0.5	0.6
{ Estimation ..	0.0	35.0	8.0	1.0	30.0	5.0	3.0	10.0	Trace.	Trace.
2 { Hand separation ..	0.0	12.4	20.4	1.2	21.6	10.6	0.5	0.5	0.7	31.9
{ Estimation ..	0.0	13.0	23.0	1.0	18.0	13.0	0.5	Trace.	0.5	31.0
3 { Hand separation ..	0.0	4.7	9.0	0.6	10.4	10.9	2.6	1.2	0.6	60.6
{ Estimation ..	0.0	5.0	6.0	0.5	8.0	15.0	1.0	1.0	0.5	62.0

It will be noted that the estimations conform reasonably well to the check hand separations. Their variation is no greater than the variation obtained in Table 1, thus indicating that the "percentage productivity estimation" of a given sample is as accurate as the result obtained by sub-sampling and the hand separation of a small sub-sample.

It is found that the percentage estimation of the original sample can be done 10-12 times as rapidly as the hand separation of a single ten gram sub-sample.

(e) *Limitations of the "percentage tiller estimation method."*

For field analyses, the "percentage tiller estimation" has been tried at the Waite Institute but does not meet with our requirements. The disadvantages of the method are :—

- (1) The difference in the weight of the individual tiller from different species.
- (2) The extreme difficulty of defining the unit in the case of prostrate and creeping species.

- (3) The absence of correlation between the field estimates based on the tiller or plant unit, and the laboratory estimations based on weight.
- (4) The disadvantage of being unable to calculate the weight of individual species where the yield and botanical analyses are known.

These disadvantages have been overcome by applying the principle of the weight estimation to the field analyses.

(f) *Estimation of percentage productivity in the field.*

For "natural" pastures a steel mesh, 2×2 links, sub-divided into four quarters by two cross wires at right-angles, has been used. For plots up to 1/10th acre, 10 random throws of the mesh are made per plot. Depending on the variability of the pasture the number of species, and the size of the individual plants, the weight of herbage enclosed by 1 or 4 of the individual square links has been allocated 10 marks. The estimated contribution of each species or group of species to the total of 10 marks is estimated. The ten estimations are summated and the data expressed as percentages. This method has been found very valuable on both "natural" and sown pastures and is now used exclusively for making botanical analyses in the field.

When the plots are large, from 1 acre upwards, and especially on grazed plots, a larger unit of estimation has been found convenient. On a cattle grazing experiment, where the sward is composed mainly of *Trifolium subterraneum* and *Lolium perenne*, a sample area of 20×10 links has been estimated fifteen times to each 2-acre plot. This sample plot has been found useful for overcoming the uneven grazing by the cattle, which renders the yield results from the square link unit extremely variable. For obtaining the main features of the sward on large plots this unit of sampling is deserving of thorough trial.

Whereas the estimation methods enable the number of analyses to be replicated at least tenfold, and the size of sample to be considerably increased, more reliance must be placed on the personal factor; it is also important that the assistants employed should be competent and skilled in the work.

The estimation methods are not sufficiently precise to detect differences that are much below 20 per cent. This is not a serious disadvantage, however, as in practice we find that differences of less than 20 per cent in botanical composition are seldom of importance, and differences of economic significance in the botanical constitution of pastures are usually much greater than this. In many of our preliminary experiments with sown species, it is a matter of success or failure, whilst differences of 500 per cent are common. The technique is therefore competent to distinguish the important and significant changes of a sward. It is not held to be absolute, and in the interpretation of the data the limitations of the accuracy are borne in mind.

(g) *Use of the camera.*

A half-plate field camera has been used fairly extensively, to provide records of features such as "growth-form" which are difficult to measure or to describe. The photographs are used to support and illustrate statistical data and are not regarded as the principal form of record.

2. THE YIELD OF HERBAGE.

The determination of the yield of pastures pre-supposes temporary or prolonged protection from grazing of the whole or representative portions of the pasture. This introduces problems not met in field crop investigations, as the absence of the grazing animal eliminates one of the most potent influences on the pasture.

(a) *Hay yields.*

The simplest method of obtaining the yield of a sward is to remove the grazing animal for the entire growing season (or the greater proportion of the growing period) and to harvest the herbage as a hay crop. The material thus harvested does not represent in yield, botanical or chemical composition the herbage consumed by the grazing animal.

On "natural" pastures composed of a number of species of essentially different seasonal growth and flowering date, the yields of hay are subject to serious criticism. In practice it has

been found that the differences between the various species as regards date of flowering and seed ripening are so great that it is not possible to cut the hay without serious loss. The earlier ripening species will have shed their seed before the later species have flowered. The recorded yield is therefore rarely equal to the true yield.

In the case of sown pastures there is less difficulty due to differential ripening, but the changes in botanical composition as a result of allowing the species to reach the "hay" stage are equally important.

It is clear, therefore, that conclusions drawn from hay cuts cannot be applied in any way as indicative of the behaviour of an identical sward under grazing conditions.

(b) *Yields under grazing.*

In endeavouring to determine the yield of a pasture under grazing conditions, it is necessary to make a series of cuts so arranged as to ensure the harvesting of herbage similar in yield, botanical and chemical composition to that available to grazing animals. The first of such a series of cuts usually presents no difficulty, as the pasture can be protected from stock and conveniently sampled immediately prior to the commencement of grazing. Difficulties occur with the subsequent cuts, however.

Firstly, the action of cutting is different from that of grazing in that the defoliation is more sudden and complete. It is also more exhaustive in the sense that no nutrients are returned to the soil in the form of animal excrement, whereas the trampling action of livestock is absent. The resulting effect is that recovery after cutting is not the same as recovery after grazing, being usually poorer. Proceeding therefore on the assumption that systematic cutting from the same unit areas cannot be justified, a second difficulty appears in the determination of the yield of herbage produced whilst the first grazing is in progress, and further, in the determination of the amount of herbage left at the completion of the first grazing. Where the grazing period occupies only one or two days, the first is not sufficiently large to affect the result, but in the case of a prolonged grazing period, running into four or five days or more, the amount of herbage produced during the grazing, particularly under favourable growing conditions, may be too large to be neglected. The second factor—the quantity of herbage left at the completion of the grazing—is serious and must be either measured or removed to the level of cutting employed. Attempts to measure this amount by means of open and protected quadrats have not been successful, owing to the variability usually present, and the impossibility of handling sufficient open and protected quadrats to overcome this variability. It is necessary, therefore, to remove the herbage to a predetermined level at the completion of the grazing and to cut to this level at the commencement of the following grazing. This has been carried out satisfactorily by Richardson (4), on an irrigated pasture at Wood's Point, South Australia, where square metre quadrats are cut at a height of one inch every 28 days and moved immediately to areas of grazed pasture alongside, the grazed pasture being trimmed to a uniform height of one inch before the quadrat is superimposed. Six replications of square metre quadrats have been found satisfactory for this purpose. There are two limitations to the general use of this method. Firstly, only a restricted number of samples can be harvested, two cuts being required per sample. Two men with a portable hand-shearing machine can harvest about 30 square metre samples (including 30 square metre clearing cuts) per day. A second disadvantage is the expense of the quadrats.

Alternatives to this method are, firstly, the usual mowing and grazing trial, or secondly, the method of sampling prior to the entry of livestock, which are then introduced in sufficient numbers to graze the pasture within the space of two or three days. This method is in use by the Waite Institute in trials at out-centres, four grazings being employed per annum and a mower or scythe being used after each grazing to ensure removal of the herbage to a uniform level. The principal difficulty experienced has been a tendency to graze selectively certain widely differing species, but in general the method has proved satisfactory for this particular type of trial.

Whatever the method adopted, it may be accepted as a general principle that the proportion of grazing to cutting should be high. Each treatment should also be grazed separately to avoid carry-over via the excreta of the grazing animal. This entails considerable quantities of fencing

materials where a large number of small plots is being employed. The method of tethering sheep on the experimental plots as developed by the Welsh Plant Breeding Station (3) offers considerable possibilities in this connection. (The method is discussed later on p. 30.)

(c) *Seasonal yield.*

The total yield per annum produced under grazing is not so important as the distribution of the yield over the season. It is suggested that results should be given as autumn, winter, spring, and summer production respectively, rather than as total production per season. So far as the Adelaide environment is concerned seasonal production is measured in early June, late July, mid-September, and at the completion of seasonal growth. Under irrigation, production is measured at 4-weekly, 6-weekly, or 8-weekly intervals. The dates chosen should remain constant from year to year whatever the nature of the season; otherwise it is impossible to compare the results obtained in different years.

(d) *Size and number of plots.*

The size of plots and number of replications depend on the nature of the pasture and on the objective of the experiment. In preliminary and exploratory work it is probably better to have small plots with a minimum of four replications. For pure species and simple seeds mixture trials field plots from 1/500th to 1/100th acre have been used at the Waite Institute. Larger plots (1/20th acre to 5 acres) have been found necessary where the plots are to be grazed by livestock. The size of plot is again dependent on whether the stock are to be carried exclusively on the plots or whether the animals are to be used as introducing the biotic factor only. In the former case, plots of the order of 5 acres are necessary on "natural" pastures, whilst in the latter case plots of 1/20th-1/10th acre have been used on sown and "natural" pastures.

In the majority of experiments it has been found impracticable to harvest the whole plot, and sampling has been adopted. The sample plots have been 10 × 5 links in area on "natural" pastures, ten samples per plot of five acres being cut. This is known to be too few; one of us has shown (Davies 1) that on ungrazed natural pasture the minimum size of plot should be 90 × 5 links replicated 9 or 10 times. The ideal size of plot, however, cannot be cut owing to the absence of a suitable cutting machine [see (e) below].

In the case of sown pastures the size of plot harvested has varied from 12.5 sq. links to 900 sq. links, with six to ten replications per treatment.

The link has proved to be the most convenient unit for plot measurement.

(e) *Method of cutting.*

The scythe, hand shears, horse-mower, lawn mower and a modified sheep-shearing machine are the principal instruments that have been employed for cutting. The horse-mower and sheep-shearing machine have proved most successful. No one of these methods of cutting can be regarded as satisfactory for all conditions, but each is adapted for certain types of experimental work.

The lawn-mower has been found to be the most useful implement by a number of workers. It has not been successful, however, under the following conditions at the Waite Institute:—

- (1) where species such as *Romulea* spp., characterized by long individual leaves, sparsely spaced and high in fibre, are present in the pasture;
- (2) where species with strong caulk are present, e.g., *Echium plantagineum*;
- (3) where the ground is uneven, and rolling of the seed bed or sward is impracticable;
- (4) where the herbage to be cut is long;
- (5) where botanical analyses are to be made on the cut herbage.

The portable shearing machine (either motor or hand-driven) can cope with these conditions successfully and has been extensively used at the Waite Institute for cuts made to simulate grazing conditions. The chief drawback is the limited area that can be cut per day, and the absence of an automatic collecting box.

The horse-mower is unsatisfactory for short or very dense pastures, and like the sheep-shearing machine, has no automatic collecting box. It does not cut close to ground level, but on



PHOTO. I: View of the portable shearing machine used for cutting small pasture plots. (Note frame and cut area in right foreground.)

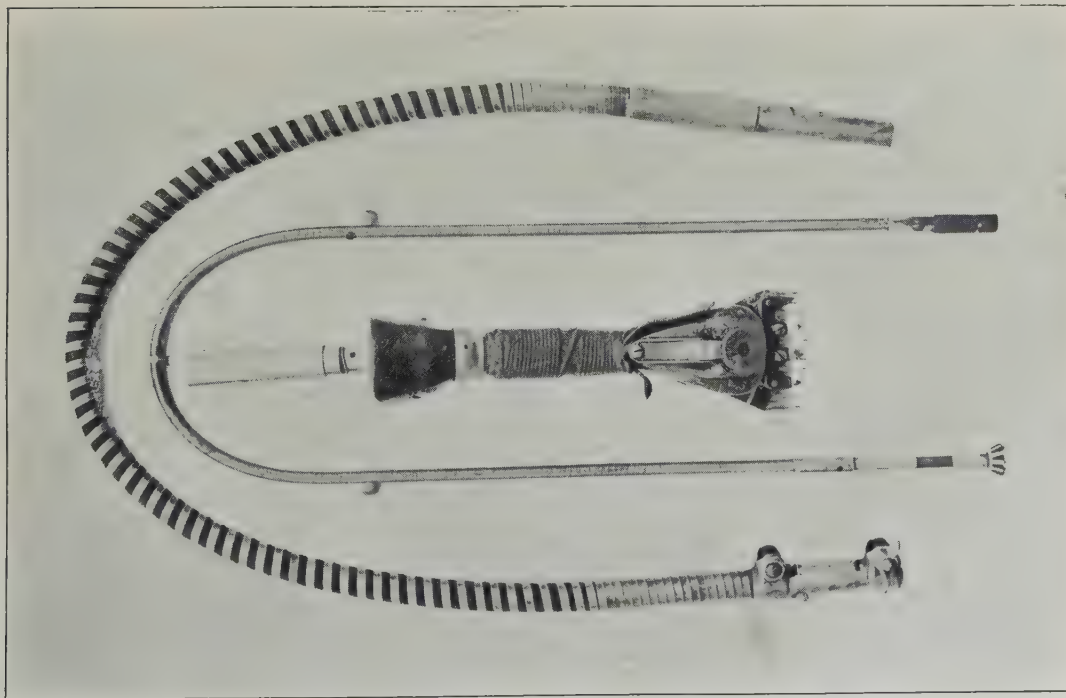


PHOTO. II: The lower part of the flexible drive and the handpiece.



the other hand is liable to vary slightly in height of cutting. The horse-mower does, however, provide a means of cutting comparatively large areas of pasture per day and has been used at the Waite Institute and at Wood's Point for cutting sown pastures at 8-weekly intervals.

3. DETERMINATION OF PRODUCTIVITY BY MEANS OF THE GRAZING ANIMAL.

An important measure of the productivity of pastures is the number of livestock which can be carried per acre over all or a portion of the year, together with the production per head in terms of wool, meat, butter-fat, etc.

In practice it is extremely difficult, if not impossible, to secure a valid measure of productivity in these terms. Firstly, the animal must be brought into equilibrium with the type of pasture on which it is to be fed, so as to nullify the effects of past feeding. Secondly, the numbers of livestock must be so arranged as to utilize fully the pasture available, yet in such a way as to be in accord with farming practice.

The principal difficulty is the inability to predict seasonal production. The nature of the season varies widely from year to year, and with it the quantity, botanical and chemical composition of the resulting herbage. It is thus impossible to predict carrying capacity on the basis of past seasons, which provide the only basis for the estimations of the future.

(a) *Measurement of carrying capacity.*

The accepted means of measuring carrying capacity has been in terms of sheep- or cattle-days per acre using (1) a variable number of livestock for varying periods of time, (2) a fixed number of animals for varying periods of time, or (3) a varying number of animals over fixed periods of time. The production value of the herbage eaten, however, and the variation in the sheep-day or cattle-day with the time of the year are not usually taken into account.

The value of the sheep-day, or cattle-day, is governed by the type of animal used. The value of the stock-day unit is also influenced by the stage of growth of the herbage when it is grazed. Thus 365 sheep-days per acre in August usually do not resemble 365 sheep-days per acre in February, and neither is necessarily equivalent to a sheep per acre for a year. A large number of sheep placed on immature herbage for a short period of time utilizes the herbage more effectively than a smaller number grazing for a longer period, and in the case of natural pastures provides a higher number of sheep-days than can be obtained by grazing the pasture throughout the season or the year with an approximately constant number of sheep.

It is evident therefore that measures of productivity based on sheep-days or cattle-days must be interpreted with caution, and that these values cannot be unreservedly converted to sheep or cattle per acre per annum.

The most satisfactory means of determining sheep- or cattle-days is the use of a fixed grazing period or periods, with a variable number of stock. The folding method (5) which has been used on natural pastures at the Waite Institute to attain uniformity of grazing is based on this principle; the period is two days per square chain or 20 days per acre, any error of judgment in stocking being corrected at the end of the first day on each square chain. This is the only method which has resulted in uniform grazing so far as "natural" pastures are concerned, and it offers distinct possibilities on both "natural" and seeded pastures, provided that the limitations of sheep-day or cattle-day values, as indicated above, are realized.

(b) *Measurement of production.*

An attempt has been made at the Waite Institute to measure the live-weight increase and the production of wool by Merino sheep on "natural" pastures, using a predetermined number of sheep. The principal difficulty experienced has been the necessity to predict the future carrying capacity on the basis of past results. To avoid any possibility of over-stocking, under-estimation of the carrying capacity must be employed, and if the numbers are not necessarily altered during the course of the experiment the carrying capacity under different treatments is arrived at before the experiment has commenced.

(c) *Tethering of sheep.*

The Scandinavian practice of tethering stock on their pastures has been successfully applied to pasture experimentation at Aberystwyth by Jones (*loc. cit.*). This method was tried at the Waite Institute in 1929, but was not maintained. Merino sheep were tethered singly on square chain plots of sown pasture composed of Wimmera ryegrass, *Phalaris* and *Trifolium subterraneum*. They were allowed to graze a circle of 50 links radius. The sheep were tethered on the plots from 7 to 15 days in succession.

The difficulties were that the sheep grazed unevenly, concentrating on a small portion of the plots, and particularly on the periphery of the circle. In addition, the tethering chain caused considerable bruising of the herbage.

In the Aberystwyth trials the plots have been reduced to between 1/120th and 1/100th acre and two sheep have been tethered to the one chain. The tendency to graze the periphery more severely has been overcome by moving the sheep twice a day a distance of approximately half the radius of the grazing circle. In this way it is possible to graze a rectangular plot, 99.5 per cent of the total area of the plot coming within reach of the grazing sheep.

The advantages of the technique are :—

- (1) fencing is not required ;
- (2) adequate and efficient replication of treatments becomes possible ;
- (3) the grazing animal is under excellent control ;
- (4) it offers a possibility of combining carrying capacity data with yield data ;
- (5) it is possible to graze each plot of a treatment independently.

There are certain practical difficulties to be overcome, such as the training of sheep to the tether chains. Stapledon reports having used four-year-old Welsh mountain wethers successfully, so that this difficulty cannot be very serious. At the Waite Institute, two-year-old Merino wethers became amenable to the chain within a few days.

4. DETERMINATION OF CHEMICAL COMPOSITION : SAMPLING FOR CHEMICAL ANALYSIS.

For routine chemical analyses of pastures, a representative sample of the herbage obtained by the agrostologist is drawn. The sample taken is necessarily small in relation to the bulk of herbage obtained from the field. To ensure satisfactory representation of the herbage, the following procedure is adopted in drawing the chemical sample :—

- (1) Immediately following the cutting of the plot, the chemist draws a sample, either by quartering the cut herbage in the case of small plots (10 × 5 links) or by taking a series of random samples of the herbage in the case of a larger plot.
- (2) The samples representing each treatment are then bulked and carefully mixed. When the herbage is short the final composite sample is drawn by the method of quartering. In the case of long herbage it is found necessary to chaff the bulked samples prior to quartering. In this way a final sample of 200-500 grams air-dry weight is obtained, ground and stored in glass containers.

In addition to the necessity for care in sub-sampling, it is necessary to take certain precautionary measures against heating, fermentation, and losses due to respiration, particularly when the field samples are drawn at some distance from the laboratory.

The most satisfactory method has been to place the cut herbage in " scrim " bags of hessian with 6 to 8 meshes per inch. In the case of large samples of wet grass it has been found practicable to hold them in good condition in these bags over a period of two or three days, including a 250-mile train journey. Considerable care is taken to aerate the samples as much as possible in a sunny or windy position. Packing of the samples for long journeys is postponed until the last possible moment. Some heating usually occurs with very wet samples, but practically none is experienced if the samples have no extraneous moisture present. The primary aim is always to promote quick drying of the herbage. In the winter period the samples are artificially dried in a steam-heated dehydrator with forced draught. During sunny weather in the spring it has been possible to dry the herbage rapidly in the hessian bags, provided that the grass is frequently agitated within the bags.

Where possible it is desirable to carry out chemical analyses of the more important individual species comprising the pasture. This necessitates hand collection, hand separation, or the cultivation of the species in pure plots or under the better controlled conditions of pot cultures. Comparisons of species should be made at the same stage of growth, e.g., commencement of flowering, as well as under similar environmental conditions.

The estimation of differences in soil or manurial treatment by chemical analyses of the bulked herbage, without regard to the botanical composition of the herbage, is unsatisfactory. These differences can be properly measured only by analyses of the same species, and preferably of the same strain, harvested at the same stage of growth.

5. SUMMARY OF METHODS IN USE AT THE WAITE INSTITUTE.

(1) The percentage estimation method, based on the weight of constituent species, is used for the determination of botanical composition, both in the laboratory and in the field.

(2) For the estimation of botanical composition in the field, a frame 2×2 links is thrown ten times at random on each plot. For plots larger than $1/10$ th acre in area, ten throws per square chain are made.

(3) In experiments of a preliminary nature, where large differences are usually involved, plots of $1/100$ th acre are estimated *in toto*, whereas on larger plots, sub-plots 10×20 links are taken at random for this purpose. On plots of one to five acres in size, 10 to 20 of these sub-plots are employed.

(4) For the determination of botanical composition in the laboratory, the herbage sample obtained from the field plots is used. When the field sample is large, it is sub-sampled down to a convenient bulk. This bulk is then divided into ten approximately equal sub-samples, and the constituent species estimated on a weight basis.

(5) Photographs are used to support and illustrate statistical data wherever possible, but are not regarded as the principal form of record.

(6) Hay cuts form one measure of production, but are regarded as having a limited value in pasture investigations, as they do not represent the behaviour of a sward under grazing conditions.

(7) A number of methods are employed to measure the yield of pastures under grazing. It is accepted as a general principle that the proportion of grazing to cutting should be high.

(8) The production during successive periods of the year is regarded as of greater importance than the total production for the year. In the Adelaide environment, cuts are made in early June, late July, mid-September, and at the completion of seasonal growth. It has become manifest that to facilitate the interpretation of the data the cuts should be made, if possible, on the same dates each year.

(9) The size and number of plots have been varied in accordance with the objective in view. For pure species and simple seeds mixture trials, where grazing is employed solely to introduce the biotic factor, field plots of $1/500$ th to $1/100$ th acre are used. Larger plots ($1/20$ th to 5 acres) have been found necessary where the plots are to be grazed individually by livestock.

(10) It has been found impracticable to harvest the whole plot in the majority of cases, and sampling has been adopted. The sample area cut has varied from 12.5 square links to 50 square links, and the replication from twice to ten times per plot, in accordance with the nature of the trial, the variability of the sward, and the size of the plot samples.

(11) A portable shearing machine, either motor or hand-driven, has been used for cutting the sample areas. When the whole plot is being harvested the horse mower or the scythe has been the cutting implement employed.

(12) Sheep- or cattle-days per acre are regarded as the most useful measure of pasture production in terms of the animal. The most satisfactory method of determining sheep- or cattle-days has been to graze the plots with a variable number of stock for fixed periods of time.

(13) The use of the live-weight increase per acre or the milk yield per acre as a measure of pasture production has been found to be unsatisfactory, because the errors involved cannot be eliminated or estimated.

(14) Folding of sheep on plots of the order of 1/10th acre has been found useful for rapid and fairly uniform grazing of pastures. The method becomes expensive on very small plots, and in this connection the method of tethering sheep offers considerable advantages.

(15) For chemical analyses, representative samples of the plots cut for yield determinations are generally taken. To promote rapid drying, the samples are placed in "scrim" bags of hessian, which allow considerable circulation of air without serious loss of herbage.

(16) Wherever practicable, chemical analysis of pure species at the same stage of growth is made, particularly where differences in soil or manurial treatment are under investigation.

In conclusion, it is felt that, for a proper evaluation of pastures, the inter-relation of the seasonal yield, the botanical and chemical composition of the pasture and the requirements of the grazing animal must be fully appreciated.

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NOTES ON BOTANICAL ANALYSIS OF IRRIGATED PASTURE*

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At the State Research Farm, Werribee, Victoria, work on irrigated pastures of mixed grasses and clovers has proceeded mainly along the lines of establishment, watering, manuring and the preliminary investigations of the biotic problems which are inseparable from the problems of effective utilization of pasture herbage.

Yield of dry matter, carrying capacity, and live-weight increases are standards of comparison in the tests.

The variations in botanical composition, due to varied treatment, were recognized as having an important bearing on features such as seasonal distribution of yield, and in 1929 botanical surveys were commenced, using the "percentage estimation" method (4), or in other words the "percentage productivity" method described by Davies (1). In addition, an estimation of the amount of bare space is made, a maximum of ten points being allotted in each 2 links square quadrat (mesh) reading. Any increase in bare space, if permanent, is usually followed by an increase in the percentage of inferior pasture plants, and this feature was of particular importance in the rate and frequency of watering tests and in grazing trials. Also, on the manurial trials of the season 1931-32, a negative correlation ($r = -0.8$) was found between bare space percentage and yield of dry matter at each cut.

The 4 square links mesh was chosen arbitrarily as convenient, but no investigation has been made to determine whether a smaller mesh might be used without loss of efficiency. It was sufficiently large to ensure that each reading would encompass a number of species, and in our opinion a larger mesh could not be used without unduly retarding the process of estimation.

THE ACCURACY OF A SINGLE ESTIMATION.

The most important question involved in the use of this and similar methods is "Can the observer's estimates be relied upon?" Direct test of this point, by separating and weighing the major species present in a series of samples which had been previously estimated *in situ*, indicated that the observer could estimate to within half a point (i.e. 5 per cent) of true values, except in some exceptionally difficult cases to be indicated later. The results of such a test (in part) are set out in Table 1.

Sections A and B of Table 1 show that for the major species, and for total grasses and clovers, the accuracy of estimation is satisfactory. In Section C, however, the estimated values are far from the true values as determined by sorting and weighing, both for major species and total grasses. The type of sample estimated in A and B was very different from that shown in C and the conclusions which may be drawn from these tables are important. It soon becomes apparent in this work that samples in which the major species are clearly defined one from the other as small patches present a more suitable medium for estimation than samples in which there is a practically homogeneous mixture of these species, such as occurred in C. In the former type, one has the advantage of being able to form an estimate on an "area occupied" basis, and then to correct that estimate on the basis of a scale of relative "weight per unit volume" for the species. Fortunately except in very open pastures at periods of slow growth the latter type of sample (C) is of infrequent occurrence, and the accuracy of the mean of a number of estimations is not greatly affected by the inclusion of one inaccurate estimate.

In the estimates of sample C, it is notable that the largest deviation from the mean of the three observers' estimates of total grass (6.0) was 0.7 (Observer No. 2). Since the most useful purpose served by this type of survey is the "spot" comparison of different pasture types, absolute accuracy is not essential as long as good comparative figures are obtained. In view of the agreement in the estimations of the three observers we may assume that the bias shown in difficult

*[See also Beruldsen and Morgan 3].

TABLE 1.—Test of accuracy of estimation of major species present on an area of 4 square links of an irrigated pasture.

A.							Field 5 S.W. 12/11/29.			
Sample No.							Estimated Values. (1)	True Values. (1)	Estimated Values. (2)	True Values. (2)
<i>Lolium perenne</i>	..	..	..	..	..	..	3.0	2.7	1.0	0.9
<i>Dactylis glomerata</i>	..	..	..	..	..	..	3.5	4.0	1.5	1.0
Misc. grass	..	..	..	..	..	..	0.7	0.1	0.7	0.8
<i>Trifolium repens</i> + <i>T. fragiferum</i>	..	..	..	..	..	..	2.5	2.9	6.5	7.2
<i>Trifolium pratense</i>	..	..	..	..	..	..	0.3	0.3	0.3	0.1
Total Grass	..	..	..	..	..	..	7.2	6.8	3.2	2.7
Total Clover	..	..	..	..	..	..	2.8	3.2	6.8	7.3

B.							Nitrogen Manurials. 26/6/31.			
Sample No.							Estimated Values. (1)	True Values. (1)	Estimated Values. (2)	True Values. (2)
<i>Lolium perenne</i>	..	..	..	..	..	..	0.2	0.2	0.7	0.9
<i>Dactylis glomerata</i>	..	..	..	..	..	..	2.8	3.1	3.3	3.7
Misc. grass	..	..	..	..	..	..	0.8	1.0	1.5	1.4
<i>Trifolium repens</i> + <i>T. fragiferum</i>	..	..	..	..	..	..	1.0	0.6	4.5	4.0
<i>Trifolium subterraneum</i>	..	..	..	..	..	..	5.0	5.0	—	—
Total Grass	..	..	..	..	..	..	3.8	4.3	5.5	6.0
Total Clover	..	..	..	..	..	..	6.0	5.6	4.5	4.0
Weeds	..	..	..	..	..	..	0.2	0.1	—	—

C.							Nitrogen Manurials. 2/7/32.			
Sample No.							Estimated Values (3 Observers).			True Values.
							(1)	(2)	(3)	
<i>Lolium perenne</i>	..	..	..	..	..	..	0.5	0.4	0.5	1.4
<i>Dactylis glomerata</i>	..	..	..	..	..	..	3.0	3.6	3.2	3.1
Misc. grass	..	..	..	..	..	..	2.0	2.7	2.1	3.2
<i>Trifolium repens</i> + <i>T. fragiferum</i>	..	..	..	..	..	..	4.4	3.1	4.0	2.1
<i>Trifolium subterraneum</i>	..	..	..	..	..	..	0.1	0.1	0.1	0.1
Total Grass	..	..	..	..	..	..	5.5	6.7	5.8	7.7
Total Clover	..	..	..	..	..	..	4.5	3.2	4.1	2.2

estimations will be consistent ; hence the value of the estimations is high, from a comparative standpoint, even when absolute accuracy on any one plot cannot be claimed. Desirable as it would be to have accurate figures, it is obvious that in those cases where such cannot be expected it is justifiable to accept the inaccurate figures which are suitable for interpretation as reasonably accurate comparisons.

TYPES OF PASTURE PROBLEM TO WHICH THE METHOD MAY BE SUCCESSFULLY APPLIED.

Used alone, the main value of this type of survey is in its application in " spot " comparisons of pasture types produced by variation of watering, manurial or grazing treatment. The percentage basis of the method greatly restricts its value for comparisons of any single plot from year to year or even from season to season. Suppose that a plot is surveyed and its composition

is determined to be total grass 60 per cent and total clover 40 per cent, and that when surveyed a month later its composition is total grass 40 per cent and total clover 60 per cent: what conclusion may be drawn, assuming that each survey is made at a fixed time after a grazing? From these figures alone, it would be impossible to determine whether the grass production had decreased relatively or absolutely. When changes of this kind are not marked, observational methods are not of much assistance in determining the nature of the changes taking place, and when four major species are under consideration the problem is insoluble. It is therefore apparent that this method, used alone, is not suitable for evolutionary studies, but it is permissible to compare the mean botanical compositions of a series of plots, by averaging the figures obtained from a number of surveys, providing the whole series is surveyed at the same time, and that a sufficient number of such surveys is made.

These considerations limit the application of the percentage estimation method to:

A. *Comparative studies* of a series of plots, coincidentally surveyed at frequent intervals.

B. *Evolutionary studies* where (a) plots are harvested and the weight of produce recorded, or (b) if plots are not harvested immediately, an estimate of the production or grazing-off of the herbage is obtained by the use of suitable sampling technique.

Having the *actual* yields from a series of plots, and knowing the *estimated* proportion of that yield contributed by the different species, we have *estimates* (which, in view of the accuracy of the botanical surveys, are sufficiently accurate for practical comparisons of all plots at any cut or season) of what may be conveniently termed the "absolute amounts" of those species which are produced by the various plots throughout the investigation.

In view of the rapidly changing character of the herbage composition in time of rapid growth, it is essential that surveys be completed on any series in not more than two or three days. This limits the amount of work which can be undertaken by a limited staff. Also, since the method is most useful when applied to plots which are either harvested or yield-sampled, it is desirable that the surveys be carried out immediately prior to mowings, and immediately before and after grazing on plots which are yield-sampled.

THE ACCURACY OF THE MEAN OF A NUMBER OF ESTIMATIONS.

The number of estimations made on each plot governs the significance of the differences shown by the survey figures. Pending investigations along these lines, it was decided to estimate, on plots up to 1/40th acre, 10 samples of 4 square links, the sums of the 10 estimations for any species then representing the estimated percentage present, by weight, of that species. Arithmetical work was thus reduced to a minimum. The choice of 10 estimations per plot was

Since it is the purpose of these notes to examine the method without prejudice, it is advisable to touch briefly on some inherent weaknesses which have been noted. Briefly, these are as follows:—

- (a) While the estimations are normally made on a ground-level basis, mowing machines remove only that portion of the herbage which is above the level of the knife. Where growth is good, the proportion of herbage not harvested is low, while on plots showing poor growth the proportion not harvested may be very high (particularly on most irrigated pastures, in mid-winter). While a mental picture of what will be left by the mower may be obtained by running the machine over a headland before commencing the survey, at best this introduces another approximation, and the efficiency of the method must be considered as greatly reduced on this type of test in the winter period.
- (b) An inaccuracy is introduced because each estimation is not "weighted" for the yield of the sample concerned. When a number of samples is taken, however, the arithmetical inaccuracy of the mean is smaller than the probable error of the mean and may be disregarded [4 (Appendix)].
- (c) A difficulty is often experienced in making the points allotted to the species present in a sample total 10 without disturbing the relative values of the allotments. For example, the proportion of total grasses to total clover on a sample may be estimated as $6\frac{1}{2} : 3\frac{1}{2}$. In the notation we have employed, "T" represents $\frac{1}{2}$ point, "t" represents $\frac{1}{5}$ point, and "Tt" represents $\frac{3}{10}$ point. We estimate that of the total grasses, considering the ryegrass as 1, the cocksfoot is 5, and miscellaneous grasses not quite $\frac{1}{2}$. The miscellaneous grasses are therefore recorded as "Tt", ryegrass as 1, and cocksfoot as 5 t. The addition of "t" to the cocksfoot figure does not materially alter the ratios of the various species, and the total is exactly 10 points. This exactitude is of great use in checking records, etc. Throughout we have adopted this policy of adding small discrepancies to the most important species in the sample, and this is the cause of such figures as "28.1 per cent white clover" in subsequent tables. It does not indicate accuracy of that order, however.

TABLE 2.—Standard Errors of Botanical Surveys.
S.W. Section Manurials, 1930-31.

Species.	Date of Survey.	No. of Days Growth.	Percentage species present.	Standard Error percentage (of a single plot between plots.	Standard Error percentage (of the mean of 10 samples) within plots.	Cut No.
<i>Dactylis glomerata</i>	27-11-30	23	30.2	17.7	10.5	5
	28-1-31	24	34.3	19.4	9.8	7
	10-4-31	23	42.7	7.9	9.3	10
Total Grass	27-11-30	23	33.1	14.1	9.4	5
	28-1-31	24	36.1	18.4	9.3	7
	10-4-31	33	44.4	7.2	9.9	10
<i>Trifolium repens</i> + <i>T. fragiferum</i>	27-11-30	23	57.5	8.7	7.9	5
	28-1-31	24	59.6	9.8	5.6	7
	10-4-31	33	41.9	10.2	13.2	10
Total Legumes	27-11-30	23	65.7	7.1	4.8	5
	28-1-31	24	61.9	9.6	5.3	7
	10-4-31	33	54.2	5.7	7.5	10
<i>Trifolium subterraneum</i>	27-11-30	23	6.2	75.4	48.5	5
	10-4-31	33	11.8	20.4	40.8	10

N.W. Section Manurials, 1931-32.

Species.	Date of Survey.	No. of Days Growth.	Percentage species present.	Standard Error percentage (of a single plot) between plots.	Standard Error percentage (of the mean of 10 samples) within plots.	Cut No.
<i>Lolium perenne</i>	29-7-31	32	25.7	11.3	14.2	1
	20-10-31	20	19.6	12.4	16.3	4
	23-12-31	21	11.9	16.5	19.7	7
	26-2-32	23	1.7	43.5	61.2	10
	23-4-32	30	3.4	66.8	44.1	12
	30-6-32	38	10.4	32.6	28.4	14
<i>Dactylis glomerata</i>	29-7-31	32	29.7	23.5	15.0	1
	20-10-31	20	27.5	26.9	16.5	4
	23-12-31	21	29.1	19.6	13.9	7
	26-2-32	23	27.9	20.7	14.2	10
	23-4-32	30	32.0	19.9	12.6	12
	30-6-32	38	71.9	12.5	6.8	14
<i>Trifolium repens</i> + <i>T. fragiferum</i>	29-7-31	32	32.2	14.8	17.4	1
	20-10-31	20	36.3	31.1	18.2	4
	23-12-31	21	53.1	9.3	9.7	7
	26-2-32	23	66.5	8.9	6.8	10
	23-4-32	30	58.5	5.1	9.0	12
	30-6-32	38	10.3	33.1	26.0	14

arbitrary, however. Two observers whose estimations constantly agreed worked in conjunction, each taking 5 samples. While it would have been preferable for each observer separately to estimate the 10 samples, it was considered preferable to enlarge the scope of the

work rather than to strain at accuracy. Replication was effected by taking 10 samples on each of three similar plots or sections of a plot. This method has been in use on the manurial and watering tests.

(a) MANURIAL TESTS.

In Table 2 are given the percentage errors "between plots" and "within plots," calculated according to the methods of Fisher and Clapham, together with such relevant data as the time of survey, estimated percentage of the particular species present, and so on. The "error between plots" is the square root of the variance (mean square) of a single plot, and, as such, is a composite of the variance within the plot (i.e. the variance of sampling) and the variance, random in nature, of soil and associated factors.

Considering "error between plots" for major species in 1931-32 surveys, and neglecting for the time the "error within plots" included therein, the number of plots which should have been surveyed in order to reduce the percentage "error between plots" to a value at which plot differences of 20 per cent for species would be significant are as follows:

Cut.					<i>Lolium perenne.</i>	<i>Trifolium repens</i> and <i>T. fragiferum.</i>	<i>Dactylis glomerata.</i>
					No. of Plots.	No. of Plots.	No. of Plots.
1	..	..	..	..	3	5	11
4	..	..	..	..	3	20	15
7	..	..	..	..	6	2	8
10	..	..	..	..	38	2	9
12	..	..	..	..	90	1	8
14	..	..	..	..	21	22	3

NOTE.—Differences of the nature of 20 per cent between the estimated percentages of a species on any 2 plots are significant if the Standard Error percentage of those plots is 7.07 per cent $\left(\frac{20}{2\sqrt{2}}\right)$

With plots of Standard Error=11.3 per cent, a difference of 20 per cent is not significant. The number of replications necessary is

$$\frac{(11.3)^2}{(7.07)^2} = \frac{128}{50} = 3$$

It is apparent that replication which would give sufficiently low errors for *all* species present in the herbage is in practice impossible over an extended period if a standard of 10 estimations per plot is consistently maintained. Reduction of the "error within plots" by increasing the number of estimations per plot is not a solution of the problem, since (assuming differences of 20 per cent are again to be considered significant) the number of estimations required per plot were as follows:—

Cut.				<i>Lolium perenne.</i>	<i>Trifolium repens</i> and <i>T. fragiferum.</i>	<i>Dactylis glomerata.</i>
				Estimations per plot.		
1				40	60	45
4	..	..		53	66	54
7				78	19	39
10	..	..		750	10	40
12	..	..		390	16	32
14	..	..		161	135	10

NOTE RE TABLE 2.—It will be noted that in some cases "error within plots" is significantly greater than "error between plots." In these cases there is some doubt as to the validity of the estimate of error "within plots"—there appears to be justification for the elimination of a gradient variation within the plots, but the arrangement of the samples does not permit this.

If replication can be made without introducing an additional source of error (which is most unlikely) the number of estimations per plot necessary would still be impracticable for one or another species at some period of the year.

As the extra work entailed in obtaining significance for all species at all surveys would be an embarrassment, we are forced to continue present methods, and to avoid erroneous conclusions by the application of the recognized standards of significance to the results.

Since *Trifolium repens* and *Dactylis glomerata* are the major species in most of the test pastures, discussion of results is usually limited to the influence of the manurial treatment on those species. Since the only manures which appear likely to be of great economic importance for irrigated pastures (from the point of view of total yield) are the phosphatic manures, it is adequate at present if the methods employed are sufficiently accurate to demonstrate the differences in botanical composition due to phosphatic manuring. Following is an extract of the percentages of white clover, manurial tests, N.W. Section, 1931-2.

TABLE 3.—Showing the percentage increases over the calculated "No-manure" values.

Percentage of *Trifolium repens* and *T. fragiferum*.

Plot.	CUT 1.				CUT 4.				
	Actual Value.	No Manure Value.	Difference.	Percentage Difference.	Actual Value.	No Manure Value.	Difference.	Percentage Difference.	
No Manure (a). ..	24.0				30.9				
Super-phosphate {	1 cwt.	24.0	26.4	—2.4	—9.1	26.5	32.9	—6.4	—19.4
	2 cwt.	29.1	28.7	+0.4	+1.4	37.2	35.0	+2.2	+6.3
	3 cwt.	34.6	31.1	+3.5	+11.2	42.8	37.0	+5.8	+15.6
	4 cwt.	28.2	33.4	—5.2	+15.6	39.8	39.1	+0.7	+1.8
No Manure (b). ..	35.8				41.1				
Percentage Difference Necessary for Significance=					50.8				
24.1									

Plot.	CUT 7.				CUT 10.				
	Actual Value.	No Manure Value.	Difference.	Percentage Difference.	Actual Value.	No Manure Value.	Difference.	Percentage Difference.	
No Manure (a). ..	41.5				55.6				
Super-phosphate {	1 cwt.	42.6	44.7	—2.1	—4.7	67.4	58.1	+9.3	+16.0
	2 cwt.	66.0	48.0	+18.0	+37.5	75.0	60.6	+14.4	+23.0
	3 cwt.	75.0	51.3	+23.7	+46.2	78.6	63.2	+15.4	+24.4
	4 cwt.	72.9	54.6	+18.3	+33.5	77.7	65.7	+12.0	+18.3
No Manure (b). ..	57.8				68.2				
Percentage difference Necessary for Significance=					14.5				
15.2									

Plot.	CUT 12.				CUT 14.			
	Actual Value.	No Manure Value.	Difference.	Percentage Difference.	Actual Value.	No Manure Value.	Difference.	Percentage Difference.
No Manure (a). ..	47.7				9.5			
Super-phosphate {	1 cwt.	50.6	51.5	-0.9	9.7	10.2	-0.5	-4.9
	2 cwt.	65.7	55.4	+10.3	11.5	10.9	+4.6	+42.2
	3 cwt.	74.3	59.2	+15.1	19.3	11.5	+7.8	+67.7
	4 cwt.	70.7	63.1	+7.6	14.0	12.2	+1.8	+14.7
No Manure (b). ..	66.9				12.9			
Percentage Difference Necessary for Significance=					8.3			54.0

TABLE 3(a).—Summary of percentage of *Trifolium repens* and *T. fragiferum* under various treatments.

						Cut 1	Cut 4	Cut 7	Cut 10	Cut 12	Cut 14
No Manure (a).	..	..	..	..	..	24.0	30.9	41.5	55.6	47.7	9.5
Superphosphate {	1 cwt.	..	..	..	..	24.0	26.5	42.6	67.4	50.6	9.7
	2 cwt.	..	..	..	..	29.1	37.2	66.0	75.0	65.7	15.5
	3 cwt.	..	..	..	..	34.6	42.8	75.0	78.6	74.3	19.3
	4 cwt.	..	..	..	..	28.2	39.8	72.9	77.7	70.7	14.0
No Manure (b).	..	..	..	..	..	35.8	41.1	57.8	68.2	66.9	12.9

NOTE: From the statistical point of view the lay-out of these plots is bad, and we are forced to make the assumption, when comparing the treatments, that the change in the percentage of white clover from one "No Manure" plot to the next is gradual and uniform in nature. On this assumption, the theoretical values designated the "calculated No Manure" values are obtained for the plots intermediate to those two "No Manure" plots, and the percentage increase over the "calculated No Manure" value for each plot is compared with the difference necessary for significance. Comparisons of this nature, for several cuts, are shown in Table 3.

Considering the results presented in Table 3:

First, except for Cut 10 (February), 1 cwt superphosphate is consistently negative, although not significantly so. On this plot, we have a close struggle between white clover (*Trifolium repens*) and subterranean clover (*T. subterraneum*), both of which respond to phosphatic manuring; it seems that the subterranean clover has some slight advantage in spring and autumn which limits the white clover percentage in summer to a value below that of "No Manure." This result is peculiar to this section of the manurial tests.

Second, on the plots treated with 2 cwt. and 3 cwt. superphosphate, although the white clover is definitely dominant over the subterranean clover, and there are significant differences in favour of superphosphate in the summer period when that species is very active in growth under irrigation, the method is not sufficiently accurate to demonstrate significant differences in the spring and winter periods. The consistency of the increases in these cuts, however, seems to justify the statement that the percentage of white clover is materially increased by phosphatic manuring. Yet, after the first large increase due to 2 cwt. superphosphate, the increases are not consistently maintained. In other words, the *quality* of the herbage in this series is not

greatly altered by dressings in excess of 2 cwt. per acre. If the "absolute amounts" are used in place of percentages, we are able to analyse the effect of superphosphate on the production of the species in pounds of dry matter, and it is then obvious (although the detailed data are not presented here) that actual dry matter production due to white clover shows significant increases with each cwt. applied, even with 4 cwt. per acre. Thus the estimated percentages enable one to evaluate changes in species-relationships (i.e. competition of species in varying environments) while the "absolute amounts" produced by each species show the combined influences of manurial treatment and environment on species-productivity.

In view of these results, and with due allowances for the limitations of the method, we conclude that the "percentage estimation" method is very useful in the elucidation of manurial problems of mixed irrigated pastures when properly used in conjunction with yield data, and that it may be applied to a large number of plots without undue labour.

(b.) RATE AND FREQUENCY OF WATERING TESTS.

In the article which gives a full account of yield etc., of these plots for seasons 1929-30 and 1930-31 (2) the errors associated with the percentage estimation method as applied to this series are considered (pp. 196 and 197), the data employed having been obtained from a test on 1/40th acre on 18th July, 1930. "This particular section was chosen as one in which a good representation of all major species was apparent, and the test was carried out at a period of the year when it was felt that maximum errors would be encountered."

At the time of writing the above, the authors were unfamiliar with the processes of the analysis of variance as developed by Fisher, and an examination of the results from the manurial tests as presented in previous paragraphs had not been made. It must now be concluded on the basis of these results that the methods of statistical analysis used in the article above were inadequate, and that it is necessary to revise the statements made.

Table 4 is abstracted from page 197 of the article in question (2).

TABLE 4.—Test of Accuracy of Botanical Survey (given as percentages).

	Total grass.	Total clover.	Ryegrass	Cocksfoot	White clover.	Sub- terranean clover.	Bare ground
Standard Error of mean, 30 estimations	7.0	2.9	18.8	10.1	11.7	14.0	13.0
Percentage of total herbage	29.2	67.4	5.1	23.8	36.2	30.3	9.6
Percentage occurrence	98	100	88	88	92	94	90
Total range of estimations	0-50	51-95	0-18	0-45	0-76	0-72	0-35
Probable Standard Error of differences shown by 2 plots of very similar composition	9.9	4.1	26.6	14.3	16.5	19.8	18.4
To be significant, differences should be of the order of	19.8	8.2	53.2	28.6	33.0	39.6	36.8

From the data in Table 4 an attempt was made to calculate the "approximate maximum error of the mean of 30 samples for any species for various degrees of importance of that species in the herbage." The assumption was made that the error was in inverse ratio to the percentage of any given species in the herbage. This assumption is justified within limits since the value of σ is governed (in part) by the percentage of frequencies at the mode of the frequency curve, of which the percentage of the species present is a good indication. But, in effect, the discussion was an analysis of the mathematical functions governing the value of σ , and in the way in which it was applied would be applicable to any population. The true causes of the variation in errors of sampling of species are the seasonal periodicities which occur; in consequence the use of a single set of results to establish general principles of sampling is invalid. It is necessary to examine the results of an *extended series* of surveys.

On the watering tests, we are unable to make an analysis of variance, except of variance "within plots," because of the experimental lay-out. One bay is devoted to each watering treatment, no replication is made, and by harvesting the herbage in 5 sections on each bay (or plot) the yield data is suitable for statistical analysis by "Student's" method.

An analysis of variance "within plots" of the estimates of white plus strawberry clover has been made for a number of surveys in 1929-31, and the results obtained for Bays 1 and 2 (6 waterings of 3 in. and 6 waterings of 4 in. respectively) are given in Table 5.

TABLE 5.—Showing mean estimated percentage of *Trifolium repens* and *T. fragiferum* on Bay 1 (6 waterings of 3 in.) and Bay 2 (6 waterings of 4 in.), the errors associated with those estimations, and the significance or otherwise of the differences between the two bays.

	6 waterings of 3 in.		6 waterings of 4 in.		Difference and S.E. of difference.	Difference significant ?
	Estimated percent- age white +straw- berry clover and Standard Error.	Estimated percent- age white +straw- berry clover and Standard Error.				
MEANS OF 5 SECTIONS (TOTAL AREA=1/8th. acre.)						
5 Dec. 1929	21.2	± 3.7	36.4	± 3.9	15.2 ± 5.4	Yes.
10 Feb. 1930	34.5	± 8.1	67.6	± 4.6	33.1 ± 9.3	Yes.
29 Apr. 1930	39.6	± 18.0	55.8	± 3.1	16.2 ± 18.3	No.
7 July, 1930	38.0	± 3.2	54.5	± 3.3	26.5 ± 4.6	Yes.
MEANS OF 3 SECTIONS (TOTAL AREA=3/40ths. acre.)						
8 Sept. 1930	23.7	± 1.8	45.7	± 1.2	22.0 ± 2.2	Yes.
24 Nov. 1930	44.8	± 5.2	73.5	± 0.9	28.7 ± 5.3	Yes.
20 Jan. 1931	61.2	± 5.9	74.6	± 3.4	13.4 ± 6.8	Yes.
4 April, 1931	56.8	± 5.5	73.9	± 4.1	17.1 ± 6.9	Yes.
27 June, 1931	30.3	± 3.1	49.5	± 2.5	19.2 ± 4.0	Yes.

This shows that the method used, that of taking estimations on each of 3 sections in each plot, was sufficiently accurate to show that a significant increase in the percentage of the above clovers was a result of the heavier watering system. Therefore, in these tests the method satisfied the requirement of speed, was sufficiently accurate, and in conjunction with the yield data, provided valuable information in regard to species-competition and species-productivity as influenced by varied watering treatment.

(c). ROTATIONAL GRAZING TRIALS.

For the details of the report on yield sampling and botanical survey technique, we would refer to Morgan and Beruldsen (4). Briefly, the plots, which are $\frac{1}{2}$ -acre, are yield-sampled before and after grazing, taking 25 and 35 well-distributed random samples respectively. The sample area, which is 3 ft. 6 $\frac{1}{2}$ in. by 1 ft. (8 sq. links), was selected arbitrarily. There is now strong evidence that this size is *not less than* the optimum for such work on this class of pasture. The surveys consist of 35 estimations, before and after grazing, using the 4 sq. link mesh, per $\frac{1}{2}$ acre. The distribution is as stated for yield samples.

Table 6 shows some typical results from which it is possible to determine the preferences of the sheep. When a sufficiently large number of observations has been made it is hoped that it will be possible to determine some of the factors which are at the root of such preferences, i.e. whether they show seasonal trends, are associated with the dominance of a species, are varied by weather conditions, etc.

TABLE 6.

Plot 8B. Dates 27/8/30 and 28/8/30. Number of sheep=60.

	Pounds of green herbage	<i>Lolium</i> <i>perenne</i> .	<i>Poa</i> <i>pratensis</i> .	<i>Dactylis</i> <i>glomerata</i> .	<i>Trifolium</i> <i>repens</i> .	<i>T. fragiferum</i> .	<i>T. subterraneum</i> .
Amount pre- sent before grazing ..	2953±250	1092±98	619±85	423±73	265±91	325±48	295±60
Amount pre- sent after grazing ..	1990±143	764±47	460±37	276±52	175±57	171±30	143±30
Amount eaten by sheep	863±288	328±109	159±93	147±90	90±107	154±7	152±67
Percentage eaten by sheep ..		30	25.7	34.8	33.9	47.4	51.6
Significant ?	Yes.	Yes.	No	No	No.	Yes.	Yes.

In these notes we are not directly concerned with the results of such investigation except in so far as the method in use can be shown to be a satisfactory one. It must be admitted that in the particular case given the sheep showed a decided preference for legumes and in particular for subterranean clover. While observational methods might have yielded the same information in a general way, it is difficult to retain a correct impression of the botanical composition of a plot of such size for comparison with its composition after grazing. This is particularly true when it becomes necessary to distinguish between such grasses as *Poa pratensis* and *Lolium perenne*. Where two species are conspicuously different, observation may be as good as the survey method, but in this case the surveys have demonstrated a preference for *Lolium* (as compared with *Poa pratensis*) which would have been difficult to show except by the detailed method.

THE RELATIVE IMPORTANCE OF THE NUMBER OF ESTIMATIONS PER PLOT AND THE NUMBER OF REPLICATES.

Davies (1) concludes that 5 replications of plots on which 10 estimations are made is the most suitable practical procedure for plots of about 1/100th acre. Our experience with plots of a similar size, but with the improved lay-out developed by Fisher, and the use of the method of analysis of variance of sampled plots formulated by Clapham, indicate that these conclusions are not general in their application, since practical considerations often necessitate a considerable deviation from them.

The choice of the number of estimations per plot and the number of replications should be governed by the nature of the differences which are to be shown as significant, and by the relative importance of the results for a single plot. In some investigations the figures for each plot may have to achieve a high degree of accuracy, in which case a minimum of 10 samples per plot may be necessary; in other investigations it may be sufficient if the means of the replicated plots are of a stipulated degree of accuracy, and the number of estimations per plot may with safety be less than 10. If experimental lay-outs are to permit a valid estimate of error between plots (according to the methods of Fisher) they must allow of at least 10 degrees of freedom for error, and it is preferable to have 20 or more. It is evident that the smallest Latin square to satisfy this requirement is one 6 × 6, in which the degrees of freedom for error between plots is 20. Even then replication of the square is advantageous. In irrigation experiments, it is desirable to replicate a treatment on as many bays as possible, in order to allow for variation in

water-absorption. Under these conditions sampling of each plot to a high degree of accuracy is not practicable, and it is better to reduce sampling per plot in order to include all replicates. The number of replicates being thus fixed, and the degree of accuracy necessary to show the expected differences to be significant being pre-determined, the number of samples per plot necessary may be calculated. On a Latin square 9×9 we find 5 samples per plot adequate.

Graph 1 in the report of Davies (1) indicates that an insufficient number of means of the smaller groups of samples (2, 3, etc) was used to determine the "actual" errors. A similar graph of the errors of "total grass" estimations (Morgan and Beruldsen 4) for figures in this connection) based on 50 means of each grouping, gave "actual" errors which varied from those of the theoretical curve in such small amount as to indicate no significant differences between "actual" and theoretical.

The criticism of the finding of Mercer and Hall that 1/40th acre was the optimum size of plot for mangolds and wheat :

"This deduction is open to criticism since had their unit been 1/100th acre instead of 1/200th acre, they would still find five such units are required. Thus the optimum size would have been placed at 1/20th acre."

is also not justified. Despite the fact that 5 replications are the optimum for *any* size of plot, the error of the mean of 5 replications of a plot *smaller* than 1/40th acre was in that particular experiment larger than that of the mean of 5 replications of the 1/40th acre and with 5 replications of a plot *larger* than 1/40th acre the reduction in the error of the mean was not commensurate with the increase in area.

* * * * *

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* * * * *

SUMMARY.

1. The "percentage estimation method" of botanical analysis, as described in these notes, is synonymous with the "percentage productivity method."

2. As far as a single estimation is concerned, the method is shown to possess the advantages of

(a) rapidity, and

(b) requisite accuracy when a good growth of herbage is present,

and the disadvantages of

(a) inaccuracy when growth is poor, as in the mid-winter, and

(b) inaccuracy on herbage of which the component species are very intimately mixed.

3. In watering and (or) manurial trials, it is in most cases practicable to take a sufficient number of readings per plot and a sufficient number of replications in order to show that differences of 20 per cent in the values of the major species are significant. Where total grasses or total clover are estimated, differences of less than 20 per cent may be shown to be significant.

4. On grazing trials, particularly where grasses very similar in general appearance are preferentially grazed, the method is more accurate than observational methods.

5. With suitable lay-out, the number of estimations per plot and the number of replications may be adjusted to a large extent to suit practical convenience without materially affecting the accuracy of the results.

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